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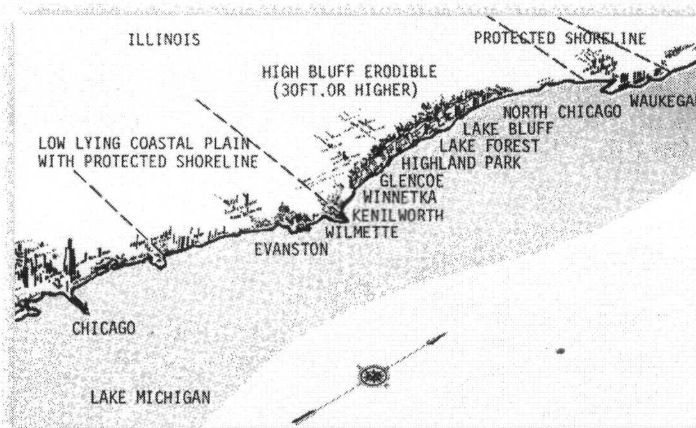
PUBLIC COMMENTS IN OPPOSITION TO CONTAINMENT REMEDY PROPOSED AS FINAL REMEDY FOR LANDFILL 6 & 7 FORT SHERIDAN, IL



Guide to Bluff Stabilization, Illinois Department of Transportation: Div. of Water Resources, The Illinois Coastal Zone Management Program

United States
Northern Illinois

Blue Eco Legal Council, and
Steven B. Pollack, executive director

Dated: January 9, 2007

to.

United States Army, and
Francis Harvey as Secretary

PUBLIC COMMENTS TO ARMY'S FINAL REMEDIAL ACTION PROPOSAL
LANDFILL 6 & 7, FORT SHERIDAN, ILLINOIS

1 Public Comments by the Blue Eco Legal Council, a membership organization for environmental advocacy, and Steven B. Pollack, Attorney, as executive director.

1.1 Blue Eco Legal Council
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1.2 Please comment on each separately numbered item. The response should not simply attack the comment, or decline to answer because the Army feels the final decision was not based upon the numbered argument, but rather explain why it disagrees. Any separately numbered item not commented on will be deemed admitted.

1.3 Included in these comments are several appendices and exhibits. These supplemental materials are referenced in various places in these comments. Some are copied from the administrative record and are included for convenience for the Army in responding to these comments. Other documents, however, are not from the administrative record and are included to supplement both these comments and the administrative record. Because the administrative record must contain all documents upon which the Army bases its decision, in order to respond to these comments these documents that are not already part of the administrative record must now be considered and shall become part of the administrative record.

1.4 Blue Eco Legal Council does not agree to have its comments aggregated with other comments unless they are identical.

2 Arbitrary Decisions In The Decision Making Process

2.1 Failure to Adequately Respond to Public Comments for the Interim Action The Army published a Responsiveness Summary to public Comments submitted during the 1996 feasibility study of cleanup alternatives for the interim remedy. Some commenters were not satisfied that the Responses adequately addressed their Comments. Specifically, Charles H. Norris, a hydro-geologist and principal of Geo-Hydro, Inc. submitted Comments on behalf of the Sierra Club and later questioned the validity of the Army's Responses. Unfortunately, the public comment process does not allow for a Reply by the commenting public to Agency Responses. Because the Army is proposing the interim remedy as the final remedy, questions about the analysis in the original decision are therefore still relevant for the final proposal. The following are Replies by Mr. Norris to the Army's Responses. The numbering system in parenthesis relates the numbers given by the Army to Mr. Norris's Comments and the Army's Responses. Please reference the original Comments and Responses in the Responsiveness Summary for the Interim Remedy for the underlying subject to these Replies.

To the degree that the final proposal has dropped excavation from the alternatives does not allow the Army to brush them off as moot. First, the Army is relying on the validity of the original interim analysis for this final remedy proposal so if the original analysis was not valid then the current proposal is therefore flawed. Second, it is inappropriate for the Army to drop the analysis of excavation from the current final proposal. See Comment 2.2. These current public comments argue that excavation, at least partial, is the appropriate final remedy so that any response must assess the current proposal against excavation even though that is not part of the Army's proposed list of alternatives.

Finally, the author(s) of any Response to these current Comments should sign their contributions. The following Reply by Mr. Norris implies that the civil engineers who responded to the interim action Comments in 1996 engaged in evasive, misleading, and incomplete answers in order to justify a preferred conclusion. Because civil engineering is a regulated and licensed profession in Illinois, I am requesting that the author(s) of the current Response sign their work.

2.1.1 (17-1) The rationale by the authors of the response justifying the discrepancy between the qualitative descriptions of waste among the alternatives is at best circular. "The differences can be attributed to the differences in risk" is a restatement of the problem, not a resolution of it. Unless and until the waste contents of Landfills 6 and 7 are adequately characterized, it is inappropriate to presume relative risks, or to use alternative-dependent descriptions to bias perceptions of the risk.

The acknowledgement by the authors of the response that these wastes must be presumed to include hazardous and/or industrial wastes (response to comments #1-1) does not absolve the government from the responsibility of determining the specific nature of the waste, rather it underscores the need for such determination. Some MSW landfills from this era that were the sites of co-disposal are among the Superfund sites.

The authors acknowledge the cost of cap replacement has not been included, because NCP doesn't require it, since it is presumed to last "indefinitely." This is a presumption that is unsupportable. The comparison of the proposed cap at this site with that of an off-site facility is deliberate misdirection. Such a site would not likely be in an urban environment, would not be adjacent to Lake Michigan, would have full engineering containment of the waste, and would be a facility acknowledged and sited for its purpose, a hazardous or special waste disposal facility. Further, as pointed out by the authors of the responses, the off-site facility would have the additional advantages of requiring up-front payment, by way of disposal fees, for facility maintenance, and the government would clearly still be liable for the waste and would be unable to "walk" at some arbitrary or budgetary point in the future.

Finally, the proffered computation of discounting cap repairs calls to mind Mark Twain's observations regarding the relationship between prevaricators and statisticians. A more meaningful calculation is that a cap repair today that costs \$3,000,000 will cost 7.7 times as much, more than \$23,000,000, in 30 years, using the suggested 7% rate for discounting/inflation.

2.1.2 (17-3) The authors apparently have failed to read "the radiological assessment report prepared by the State of Illinois Department of Nuclear Safety that was provided in the FFS as Appendix I," or they would not have misstated that the document concludes "there is no significant hazard resulting from radioactive materials potentially disposed of in Landfill 7." The report went no further than to conclude that there is no current exposure hazard at the site. Any hazard from the site with respect to radioactive waste at the site cannot be determined without characterization of the radioactive waste and any still-existing containment of that waste.

The inability of the authors of the responses to understand the inappropriate juxtaposition that was cited, and its potential to mislead, is perhaps one of the more telling examples of the mind set with which they approach this project. While it is enlightening, it is not something that lends itself to resolution or to belaboring. However, other portions of the response do need to be addressed. First, the fact that many MSW landfills of this vintage were co-disposal sites for hazardous wastes does not reduce the concern – many such sites are now Superfund sites. Second, the suggestion that such materials at this site are immobile if present cannot be supported by the existing site data. The existing site data from different media are inconsistent. The best interpretation of the inconsistency is that the leachate sampling protocols for the gas vents are grossly inadequate. Sampling and analysis of the solid waste would assist in resolving the inconsistencies, as well as helping to define source terms for risk analysis and physical properties of the wastes.

One of the inconsistencies observed was the detection of vinyl chloride in the effluent gas at the Landfill 7 gas vents, whereas there is no vinyl chloride or precursor compounds (chlorinated solvents, an expected material for this landfill) detected in the fluids collected at the gas vents. Perimeter air samples around the landfill did detect precursor compounds, and one monitoring well did detect vinyl chloride. The authors of the Responses rationalize the lack of detection in water at the gas vent wells as being due to detection limits for the water that are too high to detect dissolved vinyl chloride that would be in equilibrium with the gaseous phase, referencing an analytical detection limit in the water of 2.0 mg/L. This is simply false. The reported detection limit in Table 1-7is 0.010 mg/L, 200-fold lower than the stated number, and the analytical detection limit reported in Table 1.7 for vinyl chloride is 0.0026 mg/L, more than 760-fold lower than the number used in the response. Bottom line – at the reported gas concentrations, vinyl chloride or a predecessor compound should be observed in the liquid. That they aren't is a direct measure of the inadequacy of the leachate sampling protocol and the analysis to date.

There is an indirect measure of the understanding by the government of the inadequacy of the existing leachate analysis. The work plan for this fall [1996] at the site included sampling the gas vents again, but this time purging the water from the vents first (normal procedure). The probability that this leachate is itself hazardous material is reflected in the fact that the purged liquid is to be dumped back down the vent, rather than properly disposing of it based upon its chemical characteristics.

2.1.3 (17-5) In Response to this comment, the authors reference the response to comment 1-32. Among the assertions in that Response is the statement that "[t]he leachate collection system would intercept and collect DNAPL present." This is without question an overstatement, if not a known erroneous statement. There is no evidence anywhere in the record that the storm drainage system is positioned or open in areas where DNAPL is or may be within the landfill. It is also important to recognize that the impacts of DNAPL is not primarily on the functionality of the landfill cap, but on the composition and treatability of the landfill leachates and landfill gases. Simple flaring will not destroy some chlorinated compounds.

2.1.4 (17-6), (17-15) The authors of the responses maintain that mass balance cannot be used to verify that the low flow of 10 gpm may be leachate(s) from Landfill 6 and 7. In fact, this is one of the few methods available to independently verify the foundation of the house of cards that is based upon the assumption of current leachate drainage of 10gpm. It is clear from the data provided in the FFS that the composition of the 10 gpm is highly inconsistent with the composition of any of the leachate compositions, but that it is fully consistent with the composition of the water from storm drains upgradient to the landfills. The chemical data overwhelmingly indicate that the water that constitutes the bulk of the low-period flow is not leachate from these landfills, but rather is storm-system drainage and "that unknown buried drains still exist that historically discharged to the ravine, or directly to the storm drain pipe..." (FFS, p24.)

In response to the comments regarding the reasonableness of 13 equivalent inches of precipitation, the authors branch into what can best be considered a rambling discussion of ways that that can be accounted for without actually having precipitation infiltration of 13 inches/year. Among the more creative ideas is one that up to 3 gpm is groundwater flowing laterally into the waste, in spite of the fact that the landfills are everywhere in the FFS described as being characterized by outward gradients; i.e. groundwater flow from the landfill into the surrounding soils at rates of from 0.1 to 3 gpm, not inward into the landfill. (The outward gradient is used to justify the 10 feet of overexcavation of native soils in the dig-and-haul alternative.)

The added losses to lateral leachate seeps is dismissed as being only that due to evaporation and transpiration. The losses to such mechanisms from these wet, swampy areas (App. I, IDNS) is not a trivial amount and should have been considered in performing a reasonable water balance for the site, and not dismissed out of hand.

A check on the infiltration rates can be done by considering the seasonal head variations, as suggested in the comments. In response, rather than performing such a calculation, the authors choose merely to repeat data in the FFS, stating that seasonal head losses in the waste are about 5 feet. If the drainage porosity in the waste is as high as 10%, this seasonal drainage represents only about 6 inches of percolation, not 13 inches.

2.1.5 (17-7) The authors of the responses acknowledge that the groundwater in LF6MW04S has been impacted by leachate migration in that area.

2.1.6 (17-9) Whether or not the present site characterization is consistent with a body of regional published data is irrelevant if it does not account for site specific conditions. And while there may be a plethora of geologic data the authors of the Responses choose to interpret in a given manner, the fact is that the data also fits an alternative conceptual model that demonstrates far less isolation of the landfills.

The authors err when they opine that the erosional process of sapping does not involve an active groundwater flow system. Such flow systems define the essence of erosion by sapping as opposed to downcutting. Such a flow system does not require continuous lenses of silt, sand, or gravel, nor does the geology of the area support such systems. However, flow systems with discontinuous lenses or layers of silt, sand, and gravel that are connected by fracture systems provide the necessary flow network to develop the geomorphology of the ravines.

The authors are correct when they point out that were the sapping mechanism and the interconnected groundwater flow systems to be present and active, field evidence would include visible seeps and springs (even in the dry season), benching, and terracing. It appears that the authors, however, have apparently never been down into the ravines, based on the assertion that these features are not present. The presence of these features is apparent to anyone who takes time to climb down and brush away the fallen leaves or push aside the hydrophilic vegetation at the seeps. These readily observed and characteristic features of sapping are why the Illinois Chicago Circle geology department brings field trips to the north shore ravines; they are one of the clearest examples available in the Midwest to demonstrate an erosional process normally associated with canyon-land development in the arid west.

2.1.7 (17-10) The authors of the Response are undoubtedly aware that, while the rigorous characterization and evaluation of a dual porosity system would require far more data and different data than has yet been obtained for this site, the approximation suggested in the comment they are addressing is accurate to within a few percent and is all that is available from the data provided in the site documents They are also unquestionably aware that, while "average or bulk values for the porous medium as a whole are most commonly used [as was done in the FFS characterization] in evaluating groundwater flow rates (Domeinico and Schwartz, 1990)," neither Pat Dominico nor Frank Schwartz is advocating using the bulk porosity of the entire system for computation of contaminant travel times.

The three empirical observations called upon by the authors in support of no secondary porosity system are as applicable a system with secondary porosity as to one without. Both the first and second erroneously attribute head distributions solely to variations or contrasts in hydraulic conductivity. In fact, both phenomena discussed represent a balance between hydraulic conductivity and the flux of water through the system. Exactly the same head/gradient distribution exists even if the hydraulic conductivity is doubles, provided it is acknowledged that the mass of water moving through the system is also doubled. The significance to the site and the selected alternative is that the effectiveness of the cap and leachate drain for keeping water out of the waste and minimizing leachate production are undermined if there is an unrecognized, contributing network of secondary porosity.

The importance of the secondary porosity system is particularly significant once the leachate collection has stopped. Without withdrawing leachate from the landfills, they will resaturate and establish a gradient out of the landfill rather than into the landfill. Whether or not the secondary porosity has been yet evaluated with respect to average hydraulic conductivities, the travel time will be less through it than through an equivalent single-porosity system. Any attenuative properties of the natural system will also be reduced because of reduced contact and reduced contact time.

2.1.8 (17-11), (17-12) The authors of the responses either don't understand the intent and significance of the comment and the underlying data, or are deliberately attempting to cloud the issue. Wherever a vertical gradient is observed in or under the landfill, the gradient os downward. That is, the phreatic surface is higher than the head associated with the deeper interval. One can, therefore, project that the phreatic head at the G-

101 location is as high or higher than the G-101 head, just as the LW6MW04S head is higher than the LW6MW04D head, as seen in Table 1-2. As mapped, the phreatic head at G-101 is interpreted at an elevation of about 642 feet. As pointed out in the Response, the head at G-101, and thus the minimum phreatic head at that location, is about 653.5 feet, 10 or more feet higher than mapped. This means that the head gradient toward the manhole at the phreatic surface is significantly steeper than that mapper on Figure 1-7. Since the flux into manhole is whatever it is, the steeper gradient means that the hydraulic conductivity is lower than that implied by the Figure 1-7 interpretation. The manhole may be draining an area around itself, but that area is less than that displayed on Figure 1-7 and that suggests that drainage of both gas and liquid from the waste may be more difficult than inferred from the incorrect mapping.

2.1.9 (17-13) The lack of head data for LF6 and the described standing and ponding water make the concern more than theoretical. Further, the distance of 100 feet from the waste boundary is not necessarily significant if there are preferred pathways from the waste to the well. If monitoring points have now been installed as part of the fall [1996] program, it may now be possible to determine at least what the dry-season gradient relationship is between leachate levels in LF6 and LF6MW01.

2.1.10 (17-14) It is disturbing that, even upon review of the slug tests mentioned in the comment, no alternative interpretation was made. It is clear from the response of the wells to the slug test that the assumptions for the Bouwer and Rice interpretation method are not met by the wells. Were the Bouwer and Rice assumptions appropriate for the wells, the slug test data would have generated a semi-log plot of residual head (log) vs time (linear) that is a straight line. It is the slope of this straight line that provides the solution in the Bouwer and Rice method. However, the data do not generate this straight line. Rather, they form curvilinear patterns with a continuously decreasing slope with time. Since the measured-data trends do not conform to trends generated by hydrologic systems assumed by the method, the site hydrologic system does not conform to the system assumed by the interpretation method. In the case of LF7MW04S, partial data reported in the groundwater classification document permitted a limited evaluation of the results by the Cooper, et al. method (confined system). It appears the data conform more closely with the Cooper type curves than to the Bouwer and Rice straight line, with a hydraulic conductivity at least 5-fold greater and a lower storage coefficient. More important, however, than the revised hydraulic conductivity is the data-derived observation that even in the area of the beach and at shallow levels, the flow system appears to be a confined, not unconfined, system.

The authors acknowledge that additional hydraulic conductivity determinations are necessary to characterize the soils adjacent to and beneath the landfills. It is unfortunate that it is not recognized that this data is needed before it is appropriate to make the final selection of the alternatives for the landfills.

2.1.11 (17-16) The limitations of the MODFLOW modeling and the down-grading of its significance in the Response is appropriate and welcomed.

It is somewhat surprising that the authors to the Responses profess to not understand the critical nature of the 10 gpm figure with respect to the consideration of action alternatives, particularly given their emphasis on, and defense of, it. The fundamental significance of the 10 gpm-as-leachate assumption is that it provides the foundations upon which the interpreted fluxes through the landfill and surrounding soils are built. 10 gpm is the maximum (and stretched) infiltration rate that can reasonably be postulated for the landfills. If the 10 gpm discharge were leachate, there could be very little left that is escaping through the flanks or sides of the ravine. Since the gradients are relatively high, that dictates a very low hydraulic conductivity, without a need for testing. If the hydraulic conductivity is very low, there will be very little lateral flow into the landfill once leachate levels are reduced, and leachate levels are kept low with low leachate pumping and treatment costs. Once active management ceases, the landfill will be slow to recharge and whatever the final head configuration, water fluxes and corresponding risks will be minimal.

Correspondingly, if the 10 gpm discharge is not leachate, none of the other flux terms for the landfills are known. Lateral and downward flow could be significantly higher with correspondingly higher hydraulic conductivities. It would be more difficult to lower leachate levels and require more pumping and treatment to keep them low. Once management ceases, the drained wastes will recharge more quickly and outward fluxes will be greater.

The authors are correct in observing that any differences in the flow system will affect all action alternatives. However, it will not affect them all equally. A major difference between the capping and excavation alternatives is that the former is forever, the waste is always in the path of groundwater flow toward and through Wells Ravine.

2.2 <u>Failure to Objectively Analyze Feasible Alternatives</u> The Army, Illinois EPA and US EPA failed to objectively analyze the feasible alternatives in the interim remedy selection process.

2.2.1 Two Northwestern University students from the School of Engineering assessed the interim remedy decision making process on my behalf and concluded that the analysis was skewed in favor of the Army's preferred alternative. Instead of rewriting their report into these comments, I am instead supplementing my comments with their study by reference. This study is found in Appendix I and should be responded to as if part of the body of these comments.

2.2.2 Further proof that the original analysis was flawed when asserting containment would be effective comes from the design phase of the interim remedy. After years of study and analysis of alternatives the Army stated containment would be effective. This was in June of 1997. In December of 1997 the Army hired Charles Shabica & Associates to evaluate the containment remedy from the perspective of shoreline erosion, the main driver of failure risk for Landfill 7. In his report, Dr. Shabica states that the erosion controls, as designed, will fail. Exhibit Q. So after promoting the containment remedy as 100% sure to succeed in the FFS and Decision Document, thereby discounting the need to determine if the waste were indeed so hazardous it would trigger land disposal restrictions and need to be incinerated prior to disposal in a RCRA hazardous waste landfill, the chosen remedy was determined by the Army's hired expert as destined to fail.

The Army then hired Dr. Shabica & Associates to design and manufacture an erosion control system that the company claims will last 30 years and maybe more. Exhibit Q. The conflict of interest from having the company selling the critical systems for containment also being the expert certifying its effectiveness is troubling. The Army, IEPA, and US EPA are obviously in no position to evaluate the effectiveness claims by Dr. Shabica & Associates because their original plan as memorialized in the Interim Decision Document was totally off the mark according to Dr. Shabica. While the Army may want to stand by its expert because his company's opinion supports its preferred and less expensive option, the public is not necessarily protected by the combination of Dr, Shabica's conflict of interest and the Army's assertion that the toxicity of the waste need not be known because containment will work no matter what.

2.3 <u>Failure to maintain proper administrative record</u> The Army, as lead agency, has a duty to maintain the administrative record in a public area and to allow the public access to a copy machine. At some point this was outsourced to Kemron Corporation. Upon visiting the administrative record building in preparation for the Public Comment meeting held November 16, 2006 I found that the wall of Baker Boxes housing a substantial portion of the documents relating to the cleanup at Fort Sheridan were moved to a remote location without public access or a copy machine. This was apparently a change brought on by the remodeling of the Kemron personnel offices in the administrative record building. This change has made it difficult to access the records I need for the public comments and for litigation I was involved in regarding the transfer of Landfill 6 and 7 and plan to appeal. The record must remain available during the entire decision making process which will end with the publication of the Decision Document in the Federal Register. Because this has not occurred, Kemron and the Army have maintained an inadequate Administrative Record.

The Administrative Record will likely need to be certified for future litigation if the Army goes ahead with its proposed plan to cap Landfills 6 and 7 in spite of these comments that prove capping is not protective of human health and the environment, is not short or long-term effective, and is not a permanent remedy. To the degree that the Administrative Record is currently being mishandled by Kemron Corporation, I am concerned that the integrity of future certification for litigation will be negatively affected.

2.4 Failure to Consider all Feasible Alternatives in Final Proposed Remedy The Army has a duty under CERCLA to evaluate all feasible alternatives. During the interim action the Army appropriately considered excavation as a feasible alternative and compared it against several capping alternatives. The Army acknowledge in its Responses to public Comments that the interim action was simply a source control measure and that the current final proposal would consider issues beyond the then uncontrolled release of leachate into the lake and vinyl chloride in to the ambient air. "The Army is aware that the interim remedy addresses only the source (i.e., the waste in Landfills 6 and 7). The Army agrees that the proximity of Lake Michigan and residential areas is important in the selection of the final remedy. Therefore, the Phase II RI currently being conducted for the Department of Defense Operable Unit (DoD OU) will collect additional data regarding the effect of Landfills 6 and 7 on Lake Michigan as well as the surrounding Groundwater." Response 1-1, Interim Decision Document, Responsiveness Summary, 1997.

In its Response to the Mayors of Highland Park and Highwood Comment that the current cap was really the final remedy "under the guise of an interim solution", the Army stated "[a]dditionally, the NCP requires that the full range of alternatives be considered during selection of the final remedy." Response 1-3, Interim Decision Document, Responsiveness Summary, 1997.

Now the final proposed remedy includes the following:

> Since an interim action has been completed, the originally evaluated Alternative 1, No Action, is no longer relevant and thus is not discussed further in this Proposed Plan. Completion of the interim action also essentially invalidated further consideration of Alternative 4, waste excavation and off-site disposal if the interim action was successfully completed. Alternative 4 was not determined to be necessary to ensure adequate protection of human health and the environment. Additionally, the balancing criterion of cost (with an upper end estimated cost of over $700 million) and evaluation of other concerns regarding implementability and short term protectiveness of Alternative 4 (as presented in the FFS, and Interim Source Control Action Proposed Plan and DD) illustrated that the implementation of Alternative 4 is

not feasible. Lastly, the U.S. Navy, the IEPA, and the USEPA concurred with the selected interim remedy.

This is a completely inaccurate statement about the need to evaluate alternative 4, excavation as part of the final proposed remedy. So not only has the Army failed in its responsibility to consider the full range of alternatives in the current final proposal, specifically excavation, it used adherence to this requirement to mislead the elected officials when implementing the cap as an interim remedy.

The NCP contains no provision for essential invalidation of a feasible alternative upon successful completion of an alternate interim remedy. In fact, the NCP says exactly the opposite, that interim remedies should not be inconsistent with nor preclude implementation of a final remedy. So while an analysis of both excavation and containment in the final remedy may lead to the conclusion that one or the other is preferred, the successful completion of the interim containment remedy cannot be used to invalidate excavation from consideration in the final remedy. The reason is because interim remedies in general, and the cap on Landfill 6 and 7 specifically, serve a different purpose from a final remedy. The interim remedy is solely for the purpose of stopping uncontrolled releases while the final remedy is being analyzed. It is not inconceivable that the cap was appropriate to stop the 14,000 gallons of leachate from entering Lake Michigan each day and the release of vinyl chloride gas into the ambient air but is not appropriate for the long-term remedy needed for protection of human health and the environment. In fact, there was a delay of nine years between selection of the interim remedy and the proposal of this final remedy. The interim containment solution served its purpose by stopping these releases during the delay in getting to the point of implementing a final remedy. Now it is time to select a permanent remedy and excavation is a feasible, and I argue the only, remedy that will be protective of human health and the environment over the time in which these landfills continue to be a risk.

The balancing criterion of cost is just that, balancing. It does not, as the above quote from the final proposed remedy states, illustrate that excavation is not feasible. That turns a balancing criterion into a threshold criterion, which cost is not. In fact, the upper band of excavation is $711 million only if the waste is so hazardous as to trigger landfill restrictions that require the waste to be incinerated prior to placement in a RCRA hazardous waste landfill. It is exactly this Alice in Wonderland comparison of the unknown costs for excavation to the known cost of containment found in the FFS that caused me to get involved in this decision 11 years ago. If the waste is indeed so hazardous that is has to be incinerated prior to placement in a RCRA hazardous waste landfill then it is completely inappropriate to leave it un-incinerated in a non-RCRA landfill next to Lake Michigan. Landfill 6 and 7, if it were proposed as a RCRA hazardous waste landfill, could never get a permit because of siting restrictions for geologically unstable areas like the eroding north shore bluff and ravine environment. So if excavation would cost $711 million, it is only because the waste is of such a hazardous character to make disposal in its current location completely inappropriate. The Army analysis is designed to make excavation seem like an unknown range of outcomes, some potentially very costly, while containment is known and will work. The problem is that the range of costs for excavation represents increasing levels of risk while the Army's comparison of this range of costs to the known cost of containment ignores the changing level of risks represented by the increasing cost of excavation. The change in risk to the excavation remedy for increasing levels of hazardous waste is also a change in risk for bluff failure and the containment remedy.

The Army must fix this by considering excavation in the current final proposed remedy. Accordingly, my current Comments assume the Army is considering excavation but is relying on its original analysis from the interim action FFS in 1997.

2.5 <u>Failure to adequately characterize waste</u> – See Appendix I and Comment 2.1

2.6 <u>Misleading Assertions to the Public Regarding US EPA's Concurrence</u> The Army, and Kemron Corporation, have made misleading assertions to the public regarding the concurrence by US EPA for the current interim remedy, While US EPA did originally concur with implementation of the current cap, that concurrence was withdrawn because of Kemron Corporation's failure to use screened soil. Instead of soil screened for rocks larger than 2", Kemron used unscreened soil containing 6" rocks and clay boulders. The Army then had Hard Hat Services write up a report for US EPA arguing that the unscreened soil, together with a cap-wide rock picking effort, met the spirit of the design. US EPA disagreed that there is such a thing as spirit of design. US EPA further said its original concurrence was based on the cap being implemented as designed and also with the Army Corps of Engineers providing a final certification on the erosion controls. Since neither one of these preconditions to its original concurrence were met, US EPA indicated it would not provide regulatory closure or a covenant warranting that all remedial action had been taken and demonstrated to be operating properly and successfully. This means that US EPA no longer concurs that the interim remedy, now being proposed as the final remedy, is protective of human health and the environment. See Exhibits M and N

Kemron Corporation and the Army have repeatedly used US EPA's original concurrence to mislead the public on US EPA's current position. There is a sign at Landfill 6 & 7 showing US EPA as a signatory to the current interim action. "A determination was made that an interim remedial action at Landfills 6 & 7 would be needed, in part, to bring the landfills into regulatory compliance and to reduce the potential risk to human health and the environment. The decision document for the interim remedial action was approved in April 1997 by the USEPA and the IEPA with final signatures by the U.S. Army in July 1997." Page 5, Proposed Plan, Final Remedy, Landfill 6 and 7, Nov 1 2006. While the statement is literally accurate that US EPA was a signatory to the original determination, it is not the current position of US EPA. Even to the final moment of this proposal the Army tries to mislead the public that US EPA is still on board with the current cap. "Lastly, the U.S. Navy, the IEPA, and the USEPA concurred with the selected interim remedy." Page 13, Proposed Plan, Final Remedy, Landfill 6 and 7, Nov 1 2006. The use of the past tense is the only thing keeping this statement from being a flat out lie, but the Army clearly included this statement to imply the US EPA is on board with the current remedy.

In 40 pages of the current final proposal, the Army and Kemron have failed to inform the public about its mistakes in implementing the landfill cap and about US EPA's dissent. This is one more reason why a polluter and financially interested party like the Army cannot be trusted to make an objective analysis of its own cleanup. The Army was also not honest with the analysis of alternatives in the interim remedy analysis. See Appendix I. It is all the more reason why the Posse Comitatus act should preclude the Army from enforcing the laws of the United States including CERCLA. See Comment 3.2

3 Violation of Federal Law and Executive Order

3.1 Floodplain Management- Executive Order 11988

3.1.1 The Containment Remedy Violates Executive Order 11988 Because Excavation is a Practicable Alternative – The erosion controls are an integral part of the landfill without which even the Army admits the landfill would fail. See Exhibit I. Landfill 7 therefore sits within a 100-year floodplain. See Exhibit J (Flood Map), Exhibit K (FEMA letters), and L (EPA Docs), 44 C.F.R. § 59.1 (definition of flood or flooding includes collapse of land along lake due to waves). Executive Order 11988, Sec. 2(a)(2), however, only allows federal projects to be located in a 100-year floodplain if it is the "only practicable alternative." Because excavation is a practicable alternative, albeit not the one the Army prefers, Executive Order 11988 requires excavation over containment.

3.1.2 The Containment Remedy Violates Executive Order 11988 Because it is Inconsistent With the Standards and Criteria of the National Flood Insurance Program – Executive Order_11988, Sec. 3(a) requires that construction of Federal structures to comply with the standards and criteria of the National Flood Insurance Program (NFIP). The NFIP defines the erosion controls for Landfill7 as a "critical feature" in a "coastal high hazard area". See 44 C.F.R. § 59.1. Additionally, Landfill 7 and the associated cap are located in a "flood-related erosion area", are subject to "flood related erosion", and sit partially within the "zone of imminent collapse." See 44 C.F.R. § 59.1

The NFIP permits "only that development of flood-prone areas which (i) is appropriate in light of the probability of flood damage and the need to reduce flood losses, (ii) is an acceptable social and economic use of the land in relation to the hazards involved, and (iii) does not increase the danger to human life." See 44 C.F.R. § 60.22 The NFIP also prohibits "nonessential...public facilities in flood-prone areas." 44 C.F.R. § 60.22 While these are the planning considerations for communities wishing to participate in the NFIP, and the local and state governments surrounding Fort Sheridan do not currently participate in the NFIP, Executive Order 11988 Sec. 3(a) still allows deviation from NFIP standards "only to the extent that the standards of the Flood Insurance Program are demonstrably inappropriate for a given type of structure or facility." The participation of the State of Illinois or the communities surrounding Fort Sheridan do not demonstrably make the prohibition on non-essential public facilities like Landfill 7 in a flood-prone area inappropriate. Excavation is therefore the only practicable alternative that does not violate the standards and criteria of the NFIP. In fact, excavation is exactly what is required for human safety in 44 C.F.R. 60.22(c)(2); "Diversion of development to areas safe from flooding in light of the need to reduce flood damages and in light of the need to prevent environmentally incompatible flood plain use." Hazardous waste landfills surely qualify as environmentally incompatible flood plain use.

The NFIP criteria found in 44 C.F.R. § 60.5 requires a setback for new development based upon the rate of erosion and the anticipated "useful life" of the structure. Even though Landfill 6 & 7 already exist, in order to select containment as a viable alternative the cap and erosion controls must be implemented and are therefore considered a new development. The useful life of the landfill can only be determined by analyzing the time in which the landfill poses a threat to human health and the environment. This would be the length of time until the hazardous constituents within the landfill degrade and no longer pose a threat. The default for non-home structures is a 60-year setback although the chemicals in Landfill 6 & 7 will certainly require a longer useful life for the cap and erosion controls. But even the 60-year default would require partial excavation of Landfill 7 to account for the long term average 10" annual rate of erosion for the bluff within which Landfill 7 resides. Containment of Landfill 6 & 7 through the associated development of a cap and erosion controls therefore violates the setback criteria found in the NFIP.

3.2 Posse Comitatus – Because neither Congress nor the Constitution expressly authorize the Army to "execute the law" under CERCLA, it is illegal for the Army to act at lead agency at Fort Sheridan. The Army is lead agency at Fort Sheridan under Executive Order 12580. Executive orders are, however, management tools of the Executive Branch of government that cannot change the substantive law. By the terms of the statute, the U.S. EPA is the Administrator of CERCLA and should have been the lead agency at Fort Sheridan. It is public policy that the Army not execute the laws of the United States because it is a hierarchical, not political, branch of government. Civilian control of the Army operates only at the highest levels. The decision making process at Fort Sheridan suffered from the hierarchical structure of the Army and would have been better served by civilian control of the process. Giving Illinois EPA a concurrence role does not change the fact that the Army is executing the law.

Furthermore, the Army voluntarily sought US EPA concurrence from the beginning of the base closure in 1989, through the interim remedy in 1997, and until 2003 when US EPA disagreed with the Army regarding the effectiveness of the cap and erosion controls after implementation. US EPA's main disagreement is that the cap was not implemented according to plan and the difference may lead to unacceptable health and environmental risks. Additionally, US EPA's original concurrence was based on the Army Corps of Engineers certifying the erosion controls. Apparently Army FORSCOM has disassociated itself with the Corps. See Exhibits M, N, O, and P Consequently US EPA does not agree that the cap, as implemented, is protective of human health and the environment. A week after the US EPA made known that its concurrence was unlikely, the Army dismissed US EPA by discontinuing funding its participation. This method of dismissing dissenting views from a sister agency is why the Army cannot be trusted to execute the law under the Posse Comitatus Act.

3.3 CERCLA

3.3.1 <u>Improper use of 30 year time frame for effectiveness</u>

3.3.1.1 Flawed analysis of effectiveness – The Army had no basis to limit its review of effectiveness to a 30-year time frame. See Comment 3.3.4.2.1 - LONG-TERM EFFECTIVENESS AND PERMANENCE To the degree the Army is using this benchmark because of the RCRA sunset provision, it is improper because RCRA sites are unlike CERLCA sites in general, and Landfill 6 & 7 specifically. The assumption in RCRA that a properly planned and executed landfill that is engineered to last 30 years will last indefinitely. Landfill 6 & 7 were neither properly planned according to RCRA nor properly sited. The cap being proposed is a patchwork and is not entitled to the same presumption as a RCRA site.

3.3.1.2 Flawed design of erosion controls in 100 year floodplain – The second way that the arbitrary use of thirty years defeats the overall requirement to implement a permanent remedy under CERLCA is that the erosion controls for Landfill 7 were designed using 30-year values. See Exhibits Q, R, and S As stated in Comment 3.1, these erosion controls sit within a 100-year floodplain. When a 100-year storm event occurs, the erosion controls will presumably be inadequate because they are based on 30-year storm event values. Even if it were not arbitrary for the Army to base permanence and long–term effectiveness on a 30-year time period, designing the erosion controls based upon 30-year storm and wave values will not ensure that the erosion controls will be effective for 30 years. A 100-year storm can occur at any point in the thirty years the Army claims represents a permanent remedy.

3.3.2 Dismissal of US EPA's Non-concurrence Violates CERCLA – Because the Army invited US EPA oversight, then disagreed with criteria asserted by US EPA as regards unauthorized design changes, and finally disregarded US EPA's criteria that the cap be implemented in accordance with the interim decision document and design document, the Army has violated Section 120(a)(2) of CERCLA. This section states "[n]o department, agency, or instrumentality of the United States may adopt or utilize any such guidelines, rules, regulations, or criteria which are inconsistent with the guidelines, rules, regulations, and criteria established by the Administrator under this chapter." The Army had argued for "spirit of design" criteria whereas US EPA rejected this criterion. See Exhibit M and N. This provision of CERCLA dealing with Federal Facilities does not allow the Army to now disregard the criteria it sought by US EPA. The US EPA's criteria that spirit of design may not be used in the cleanup at Landfill 6 & 7 is now binding on the Army. The cap, as implemented with rocks larger than 6", instead of screened for rocks larger than 2", is not according to the criteria laid out by US EPA. US EPA's view that the Landfill cap is not Operating Properly and Successfully because of this deviation (See exhibits M and N) is binding on the Army because the Army may not use a criterion different than US EPA under Section 120(a)(2) of CERCLA.

3.3.3 Failure to Achieve Regulatory Closure – The landfill cap, as implemented, does not achieve regulatory closure. See Exhibit M, N, and T. Even though the US EPA determined that there was no regulatory closure required of it under CERCLA, in fact 42 U.S.C. § 9620(h)(3) requires a covenant warranting that all remedial action has been taken and demonstrated to US EPA to be operating properly and successfully (OPS). As US EPA pointed out in Exhibit N, the only regulatory closure it might provide is if the Army chose to transfer contaminated federal property by deed or lease that would trigger the covenant requirements. The Army did in fact transfer landfill 6 & 7 to the Navy in 1993, thereby triggering the covenant requirements and in 2005 transferred the adjacent land contaminated by Landfill 6 & 7, triggering both the covenant and consultation requirements. US EPA has said it does not concur that the cap, as implemented, is protective of human health and would not warrant the cap as OPS. The Army's implementation of the landfill cap, in conjunction with the transfers, therefore violates Section 120(h)(3) of CERCLA which requires regulatory closure in the form of a covenant from US EPA.

3.3.4 Nine Criteria – CERCLA requires that the Record of Decision be founded on a feasibility study[1] evaluating each proposed remedy against nine criteria and also a comparative analysis of the relative performance of each remedy for each criterion.[2] Two of the criteria, overall protection of human health and the environment and compliance with applicable or relevant and appropriate requirements (ARARs) are threshold requirements that each remedy must meet to be eligible for selection.[3] The five that are considered primary balancing criteria are long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost.[4] Finally, state and community acceptance are modifying criteria.[5]

3.3.4.1 <u>THRESHOLD CRITERIA</u> Relocation is the only viable remedy because containment of the waste fails the threshold requirement for being protective of human health and the environment. CERCLA requires that a remedy meet the

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[1] 40 C.F.R. § 300.430 (e)
[2] 40 C.F.R. § 300.430 (e)(9)(ii)
[3] 40 C.F.R. § 300.430 (f)(1)(i)(A)
[4] 40 C.F.R. § 300.430 (f)(1)(i)(B)
[5] 40 C.F.R. § 300.430 (f)(1)(i)(C)

threshold requirements, with the exception that an ARAR may be waived under certain circumstances, in order to be eligible for selection.[6]

3.3.4.1.1 1. OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT - This criterion "draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs."[7]

3.3.4.1.1.1 CONTAINMENT - Containment will not be protective of human health and the environment because it is not a long-term effective or permanent remedy. Because Lake Michigan is a major source of regional fresh drinking water, even a balanced assessment of risks would disfavor containment. In this case, the risks are not balanced because of inevitable coastal erosion. While short-term effectiveness is accomplished because the cap is already in place as part of the interim action, the complete lack of long-term effectiveness at containment automatically disqualifies this remedy as being protective of human health and the environment.

3.3.4.1.1.2 RELOCATION - Relocation is protective of human health and the environment. While there are short-term effectiveness risks to relocation, even the Army admits, "[e]ngineered controls such as enclosures with air treatment systems (e.g., carbon adsorption) are reliable."[8] Relocation, however, is the only remedy that is effective at keeping the waste from entering Lake Michigan.

3.3.4.1.1.3 COMPARATIVE ANALYSIS - While a cursory review shows that the two alternatives are balanced, with containment being stronger in short-term effectiveness and relocation being stronger in long-term effectiveness, relocation is the only remedy that is protective of human health and the environment because containment is not effective at all. The nine criteria are not a mathematical formula where one simply tabulates which remedy has the higher score. "The purpose of the

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[6] 40 C.F.R. § 300.430 (f)(1)(i)(A)

[7] 40 C.F.R. § 300.430 (e)(9)(iii)(A)

[8] *Fort Sheridan Landfills 6 & 7-Final Focused Feasibility Study* 1996 Pg 227

remedy selection process is to implement remedies that eliminate, reduce, or control risks to human health and the environment."[9]

The FS analysis does not adequately quantify the risks for each remedy or compare the risks for remedies on an equal basis. One is struck by the different characterization of the waste between the Army's responses to public comments regarding containment, and the risk associated with the lack of characterization in the Army's FS analysis of excavation. The Army states that "sufficient information is available to determine that Landfills 6 and 7 are sufficiently similar to municipal solid waste (MSW) landfills that implementation of a presumptive remedy is appropriate" and "...the concentrations of the compounds observed above detection limits are, in fact, relatively low in comparison to literature values for MSW leachate."[10] But then in description of excavation the Army states, "[n]o testing has been performed on the waste to determine if the waste is characteristically hazardous. The wastes could potentially contain constituents at such concentrations that land disposal restrictions would prohibit disposal in a landfill unless treated by incineration or other suitable means" and then, in further contradiction to the assumptions used to justify containment, "IEPA considers the waste to be hazardous based on the types of waste placed in the landfills and on the constituents detected in the landfill gas and the shallow groundwater, unless proven otherwise by further testing."[11]

The Army then goes on in the FS to use the lack of characterization, and the potential for very hazardous waste, to spotlight the potential risks of trucking 26,000 loads of hazardous waste through residential streets, to highlight the large disparity in cost with various waste composition, to

[9] 40 C.F.R. § 300.430 (a)(1)

[10] *Responses to Comments Interim Action-Fort Sheridan Landfills 6 and 7.* Response to Cities of Highland Park and Highwood 1-1

[11] *Fort Sheridan Landfills 6 & 7-Final Focused Feasibility Study* 1996 Pg 218-219

explore the risks of exposing such hazardous waste to the air, and to question the potential lack of public acceptance to excavation. For the containment remedy, however, the lack of characterization did not matter because the cap was presumed to be 100% effective at containing the waste and gas.

The Army, in the interest of making an objective comparative analysis, should either apply the presumption of low level waste used in the containment analysis to the excavation alternative, or more appropriately, should analyze the containment remedy for catastrophic failure based on the range of potential waste characterization. What was done, however, was arbitrary and capricious and designed to elicit a positive response to their preferred remedy and a negative response to the relocation remedy.

The Army further diminishes the environmental benefit of relocation by continuously assessing the burden to the receiving landfill. It is as if relocation is only a benefit if the waste disappears after leaving the shore of Lake Michigan. Implicit in this misdirection is that relocation is unnecessary so the burden on the new location equals the benefit to this location. This was brought up in the FS analysis of overall protection of human health and the environment[12], long-term effectiveness and permanence[13], reduction of toxicity, mobility, and volume[14], and state acceptance[15]. The FS analysis should not use the fate of the waste to counterbalance benefits because relocation would only be chosen on the presumption that the onsite risks are unacceptable.

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[12] Id. At 223
[13] Id. At 224
[14] Id.
[15] Id. at 238

3.3.4.1.2 2. COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

3.3.4.1.2.1 Containment

3.3.4.1.2.1.1 Executive Order 11988 – The prohibition found in Executive Order 11988 is applicable because, as argued in Comment 3.1, it applies to federal projects proposed in 100-year floodplains and the erosion controls extend into this floodplain. These requirements are also relevant and appropriate because they counsel against exactly what the Army is now undertaking, development in a 100-year floodplain, within the zone of imminent collapse under the NFIP, and containing no construction setback as required under the NFIP.

3.3.4.1.2.1.2 Construction Setback Requirements – Construction setback requirements found in the National Flood Insurance Program are applicable under Executive Order 11988 as explained in Comment 3.3.4.1.2.1.1. The criteria and standards in the NFIP are also relevant and appropriate because they deal with construction in flood prone areas like Landfill 7. Specifically, they require "[d]iversion of development to areas safe from flooding in light of the need to reduce flood damages and in light of the need to prevent environmentally incompatible flood plain use." As argued in Comment 3.1, construction of Landfill 7 is within the zone of imminent collapse under the NFIP and violates the requirement to be set back by a measure of the long term rate of erosion and the useful life of the project.

Other setback requirements which are both applicable and relevant and appropriate are found in the USGS study (Exhibit C) and the Army Corps of Engineers guidance documents (Exhibits A and B). They are applicable because they deal with the bluff erosion that threatens the long-term permanence and effectiveness of the erosion controls protecting Landfill 7 against catastrophic bluff failure. They are appropriate and relevant because containment is not the only option. These guidance documents inform the decision between containment and capping and counsel towards excavation, at least partial, as the option most closely resembling a construction setback. Equally important is the fact that the two guidance documents are from the lead Agency itself and represent a determination that erosion controls are not permanent protection for shore development.

3.3.4.1.2.1.3 RCRA Siting – RCRA, while not applicable to landfills existing prior to 1980, contains siting prohibitions in geologically unstable areas that are relevant and appropriate. They are relevant because landfill 7 sits in a geologically unstable area, inside a 70-foot high eroding bluff. These siting prohibitions are appropriate because the decision to contain Landfill 7 is not a foregone conclusion but rather one of two feasible alternatives that includes excavation. Excavation will place the waste in a properly permitted RCRA hazardous waste landfill which by its requirements will not be in a geologically unstable area. Containment does not follow the siting requirements of RCRA and is therefore not as desirable an alternative as excavation.

3.3.4.1.2.2 <u>Relocation</u> – Relocation through excavation removes the waste from the erosion hazards defined in the above ARAR's.

3.3.4.1.2.3 <u>Comparative Analysis</u> – Because these various ARAR's are consistent in opposing exactly the kind of construction required to contain Landfill 7, both as to floodplains and geologically unstable areas, relocation through excavation is the only practicable alternative.

3.3.4.2 PRIMARY BALANCING CRITERIA Long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost are considered primary balancing criteria.[16]

3.3.4.2.1 **3. LONG-TERM EFFECTIVENESS AND PERMANENCE** This criterion assesses the effectiveness of the remedy and the certainty of success.[17] Factors considered are uncertainties of containment controls, the characteristics of the residuals including toxicity and volume, assessment of the potential need to replace technical components such as the cap, and the risks posed if replacement is needed.[18]

3.3.4.2.1.1 CONTAINMENT The modified RCRA cap will not provide effective containment because the unique geological processes affecting ravines and coastal bluffs along Lake Michigan create multiple pathways and risks for the waste to enter Lake Michigan. The U.S. Geological Survey, Army Corps of Engineers, University of Wisconsin Seagrant, and FEMA have conducted comprehensive coastal erosion studies since 1986. Each study concludes that in the long run, defined variously as 30 to 100 years, coastal engineering will fail to protect against bluff recession and that the only viable strategies are construction setbacks and relocation of existing structures from the Erosion Hazard Zone.[19] This marks a change from older studies that presumed at-risk structures inside the Erosion Hazard Zone could be permanently protected using coastal armoring.[20] Even where at-risk structures are deemed immovable and armoring is used as a last resort, the property owner is advised that armoring simply changes the balance of risks over certain timeframes but does not eliminate the risk of catastrophic failure over

[16] 40 C.F.R. § 300.430 (f)(1)(i)(B)
[17] 40 C.F.R. § 300.430(e)(9)(iii)(C)
[18] 40 C.F.R. § 300.430(e)(9)(iii)(C)(1)(2)
[19] U.S. Army Corps of Engineers, Detroit District and University of Wisconsin Sea Grant Institute. *Living on the Coast.* 2003. Pg. 35
[20] U.S. Army Corps of Engineers, Detroit District and University of Wisconsin Sea Grant Institute. *Living on the Coast.* 2003. Pg. 1

longer periods. The Army has not made allowance for any coastal erosion over the indefinite timeframe Landfill 7 will remain in place.

The Army improperly limited the assessment of long-term effectiveness to the thirty-year time frame used for calculating Net Present Value (NPV) in the cost criteria.[21] The NPV allowance for discounting simply recognizes the need to standardize comparisons between remedies and, additionally, that at a certain point expenditures discounted into the distant future have little impact on present value. **The National Contingency Plan, however, mandates "that remedial action measures are cost-effective over the period of potential exposure to the hazardous substances or contaminated materials."[22]** The period of potential exposure for the containment remedy is therefore the period in which coastal erosion threatens the structural stability of the bluffs encapsulating the waste. Landfill 7 will remain a potential exposure threat indefinitely if left in place as proposed under the containment remedy. The landfill containment remedy must therefore be analyzed for long-term effectiveness and permanence over an indefinite time frame, not just thirty years.

BLUFF EROSION-EFFECTIVENESS

The containment remedy will not be effective in the long term because coastal erosion will eventually claim chunks of landfill waste and require ongoing engineering to re-protect the bluff face. Containment will not achieve permanence because landfill stability will become increasingly precarious over time as erosion eats away at the erosion protection and the adjacent bluffs. Because the landfill waste resides immediately inside the constructed bluff face, the Army is assuming

[21] Thompson, Owen. US EPA E-Mail Communication April 28, 2003
[22] 42 U.S.C.A. § 9605(a)(7)

100% mitigation of shore erosion and bluff recession when it claims containment will be effective. This assumption is not supported by experience, studies by government agencies on coastal erosion, and government agency recommendations and requirements for coastal property owners.

Coastal landowners along the Great Lakes have fought against the active erosion of their property for the better part of a century. The basic premise of shore protection is that narrow beaches allow waves to run up the base of the bluff and cause accelerated bluff recession whereas wide beaches dissipate the wave force before arriving at the base of the bluff. Groin fields have passively protected much of the North Shore coast of Lake Michigan since 1937. Driving sheet piling into the lakebed perpendicular to the shore creates a groin. Groins trap the sand as it moves southward along the shore in what is called the littoral transport system. Because the quantity of sand is fixed, and is mostly supplied by the eroding bluffs[23], past shore protection based on sand trapping has proved ineffective.[24] This is because groins only work where a single property owner has one and "accumulates" the sand before it is transported to the adjacent down drift property.[25] Where groins operate up drift, and in fact all along the shore, each groin catches the available sand and no net gain in beach width is realized by any property. Additionally, an emerging understanding of the dynamic nature of the coastal erosion process has shown the fallacy of modern shore

[23] Colman, Steven M. and Foster, David S. A Sediment Budget for Southern Lake Michigan: Source and Sink Models for Different Time Intervals. U.S. Geological Survey, Woods Hole, MA 1994

[24] Jibson, Randall W and Odum, Jackson K. *Rates and Processes of Bluff Recession Along the Lake Michigan Shoreline in Illinois.* U.S. Geological Survey, Denver, Colorado, 1994. Pg. 149 "The fairly uniform regional retreat rates between the early period of less shoreline engineering and the late period of more intensive shoreline engineering indicate that, although shore-protective works may have altered the spatial distribution of retreat rates, they had little effect on the overall rates of retreat. The absence of correlation between groin construction and retreat rates argues against the conventional wisdom at the time of their construction-that groins would produce wider beaches that would protect bluffs from wave attack."

[25] U.S. Army Corps of Engineers, Detroit District and University of Wisconsin Sea Grant Institute. *Living on the Coast.* 2003. Pg. 30 "This borrowing makes neighbors' unprotected coastal properties more vulnerable to damaging wave attack."

protection. Trapping the sand deprives the littoral transport system of material used by the nearshore zone to cover the finer textured lakebed.[26] The unprotected lakebed profile is steepening because of underwater wave attack and bluff recession is actually accelerating.[27]

Several Great Lakes coastal erosion studies have been conducted and guidance documents published in recent years. In every case, the conclusions are that coastal armoring is the least preferred alternative for protection of structures. Instead, construction and relocation setbacks from the Erosion Hazard Zone are preferred. The setback is based on two variables, expected useful life of the structure and the annual erosion rate. The difference in the recommendations of the various guidance documents centers on the length of time appropriate for human planning. In no case is the useful life of the structure assumed indefinite, as is the assumption for Landfill 7.[28]

The United States Geologic Survey conducted a bluff recession study in 1994 focused on the particular stretch of high erodible bluff within which Landfill 7 resides. The study partitioned the bluff between Wilmette and Waukegan into 300 segments and measured bluff recession by overlaying aerial photographs spanning from 1872 to 1987. The study further differentiated the periods before and after 1937.[29] One reason for the differentiation was to assess various factors presumed to affect recession rates such as lake level and shore protective devices.

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[26] Dr. Chrzastowski, Michael J. *Geology of the Illinois Coast: Present Understanding and Future Challenges.* 65th Meeting of the Coastal Engineering Research Board (CERB) 1997

[27] Id.

[28] Responsiveness Summary, Proposed Remedial Action Plan for the Interim Action at Landfills 6 and 7, 124/22/97, Response 12-7 Pg. RSR-39

[29] Jibson, Randall W and Odum, Jackson K. *Rates and Processes of Bluff Recession Along the Lake Michigan Shoreline in Illinois.* U.S. Geological Survey, Denver, Colorado, 1994. Pg. 135

As shown in Table 1, the two segments of bluff in which Landfill 7 resides recessed 40 meters, or about 131 feet, in the 115 years studied.[30]

Table 1

Bluff Segment	Total bluff-top recession (m)		Average annual recession rate (m/yr)	
	1937-1987	1872-1987	1937-1987	1872-1987
173	20	40	0.40	0.34
174	0	40	0.00	0.34

The major conclusions of the study are (1) that shore protective devices had no detectable effect on recession rates between the two periods, (2) that temporal and spatial differences existing between adjacent bluff segments give way over longer periods of time because the bluffs erode in an overall parallel manner, (3) that the anticipated life of structures near the bluff should be assessed for erosion over a 50 to 100 year time frame and (4) that any construction along the coast expected to last 100 years should be set back a minimum 65 to 80 feet.

In response to a public comment about the inconsistency between the indefinite Landfill 7 timeframe and the findings of this study,[31] the Army defended the containment decision by quoting the line of the study, "[t]herefore, the data and conclusions from this study are relevant for regional planning rather than for site-specific engineering"[32], as a reason for not applying the conclusions of this study to the proposed containment remedy. This response is the only indication the Army

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[30] Jibson, Randall W and Odum, Jackson K. *Rates and Processes of Bluff Recession Along the Lake Michigan Shoreline in Illinois.* U.S. Geological Survey, Denver, Colorado, 1994. Open-File Report 03-231
[31] Responsiveness Summary, Proposed Remedial Action Plan for the Interim Action at Landfills 6 and 7, 124/22/97, Response 12-7 Pg. RSR-40
[32] Jibson, Randall W and Odum, Jackson K. *Rates and Processes of Bluff Recession Along the Lake Michigan Shoreline in Illinois.* U.S. Geological Survey, Denver, Colorado, 1994. Pg. 150

even noticed this study because it is not discussed anywhere in the RI/FS.[33] The Illinois EPA also seems to place great stock in the fact that the USGS study "did not evaluate the effectiveness of site-specific erosion control projects; it was a regional study intended to be used in regional planning."[34] The fact that the study is meant for regional planning, however, does not mean the processes affecting the region and conclusions regarding long-term parallel recession are not applicable to specific sites within this region. The Army conveniently left out of their response the very next line stating "[a]ny planning for construction near the bluffs, however, must anticipate some amount of bluff recession and stipulate sufficient setback to insure the integrity of structure for its anticipated life."[35]

There are several ways to interpret the site-specific caveat. The least reasonable interpretation is that the powerful forces affecting the general region, for which the study intends to give general construction-planning guidance, simply do not apply to site-specific engineering decisions that may be contrary to the guidance. The more reasonable interpretation is that the site specific data contained in the study should not be used to make site-specific engineering decisions. The study went into depth regarding the two types of bluff material comprising the North Shore bluffs that have a short-term differential in recession rates yet even out over time.[36] The caveat might simply have been a warning to not make site-specific engineering decisions based on the particular bluff material at a specific site.

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[33] Walsh, Don and Liberman, Polina, *Fort Sheridan Landfills 6 & 7 Closure.* Department of Civil & Environmental Engineering, Northwestern University on behalf of Chicago Environmental Law Clinic August 2003 pg 29.

[34] Cipriano, Renee. Director, Illinois EPA. *Personal letter* Dec. 23, 2003

[35] Jibson, Randall W and Odum, Jackson K. *Rates and Processes of Bluff Recession Along the Lake Michigan Shoreline in Illinois.* U.S. Geological Survey, Denver, Colorado, 1994. Pg. 150

[36] Id. "Although bluff segments composed of materials more susceptible to surface erosion and landsliding than adjacent segments will experience anomalously high rates of retreat for limited periods of time, the data indicate that rates in such areas will eventually decrease and allow adjacent segments to 'catch up'."

The study does not say that site-specific engineering, including erosion engineering, should be avoided. The conclusions allow for the possibility that site-specific engineering can protect discrete sections of bluff against recession over short periods of time. Maybe even the thirty years the Army thinks is required under CERCLA. The study concludes, however, that over longer periods of time such as 50 to 100 years, spatial variations give way to long-term parallel bluff retreat. To say that this conclusion is not applicable to this specific remedy, which the Army concedes has an indefinite lifespan,[37] is a purposeful misuse of this caveat, an erroneous use of the thirty-year time frame for analysis, and an arbitrary and capricious disregard of credible conclusions contrary to the proposed containment remedy.

The Army deliberately defining the CERCLA analysis timeframe as thirty years causes much of the current controversy. As stated above, CERCLA actually requires effectiveness to be assessed over the period of potential exposure to the hazardous substances or contaminated materials."[38] A serious misuse of this thirty-year timeframe was in the design engineering of the erosion controls. The design life of the shore protective system is given as thirty-years which in turn is based on thirty-year values for various assumptions.[39] These engineering controls are within[40] a regulatory 100-year floodplain according to the FEMA floodplain maps[41]. Even though the useful life of the landfill is assumed to be indefinite, the protections against erosion are designed to withstand wave and lake levels experienced every thirty years. On its face this brings up two possible failure scenarios. First, after thirty years the

[37] Responsiveness Summary, Proposed Remedial Action Plan for the Interim Action at Landfills 6 and 7, 124/22/97, Response 12-7 Pg. RSR-39
[38] 42 U.S.C.A. § 9605(a)(7)
[39] *Draft Report, Design of Shoreline Protection Interim Remedial Actions, Landfills 6 & 7,* Fort Sheridan, Illinois, Rev 5/22/98 Sec. 2-3
[40] Schein, David, Senior Program Manager, Dept. of Homeland Security, FEMA Region V. *E-mail correspondence.* May 19, 2003
[41] FEMA Floodplain Map, *Panel 17097CO283F,* Lake County, IL

condition and effectiveness of the shore protection devices will be degraded. It is unclear what the Army plans to do after thirty years when the shore protection system has outlived its design life. Second, these protections may not even last thirty years if 100 year wave and lake levels occur.

Even if the thirty-year design will be effective at protecting the current east face of Landfill 7 for thirty years, the future condition of the containment remedy will be operating on a whole new set of variables from those of today. First, the Army states, "the relatively slow rate at which recession may occur will allow for monitoring and installation of structural controls that can be expected to be effective indefinitely."[42] On the issue of flanking erosion whereby adjacent property erodes while Landfill 7 does not, "controls would be 'wrapped around' the end and extended as far as necessary."[43] Bluff recession actually occurs as sudden sporadic events, so if the adjacent property sloughs off and exposes Landfill 7 to flanking erosion, will the Army be able to add flanking protection quick enough to avoid catastrophic failure? Will the new patches be wrapped around the existing shore protection system itself at the end of its useful life? It is not even clear that such flanking protection can be successively implemented because there is nothing in the literature describing this kind of permanent protection through post-failure patchwork. The conclusions of the USGS and ACE studies do not support this bald assertion of indefinite effectiveness.

Taking the hold-at-all-cost strategy to its next logical conclusion, the cohesive strength of a peninsula, exposed on three sides to erosion, cannot be assumed to be as great as the cohesive strength of being parallel to an adjacent 70-foot high clay bluff. The protruding bluff will

[42] Responsiveness Summary, Proposed Remedial Action Plan for the Interim Action at Landfills 6 and 7, 124/22/97, Response 12-7 Pg. RSR-39
[43] Id. at RSR-40.

become an encapsulating shell and cannot be ascribed the same geological characteristics as a solid clay bluff. Therefore, as the Landfill 7 peninsula extends further away from the adjacent shore face, catastrophic failure becomes increasingly likely.

The Army simply states "[t]he extreme eastern end of Landfill 7 will not be allowed to be impacted: it will either be protected by conservatively designed engineering controls that have been long-used for protection of waterfront structures or, if and when necessary, enough of the east face of the landfill removed to provide stable conditions."[44] These long-used engineering controls are the same that the Army characterized as having "apparent variations in effectiveness at reducing bluff recession rate[s]."[45] There is no variation in effectiveness because, in fact, the study which the Army is referencing says "The absence of correlation between groin construction and retreat rates argues against the conventional wisdom at the time of their construction-that groins would produce wider beaches that would protect bluffs from wave attack."[46] These same long-used engineering controls selected by the Army in the Remedial Action Plan were later predicted to fail by Dr. Shabica during the design review phase. Dr. Shabica then proposed an entirely different system of his own company's design.[47]

The Army then erroneously attributes to the authors of the USGS study that "newer groins and other control measures should provide improved control of recession"[48] when in fact the USGS study specifically states "existing data, however, are insufficient to evaluate the effects of the

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[44] Id.
[45] Id.
[46] Jibson, Randall W and Odum, Jackson K. *Rates and Processes of Bluff Recession Along the Lake Michigan Shoreline in Illinois.* U.S. Geological Survey, Denver, Colorado, 1994. Pg. 149
[47] Shabica, Charles W. and Charles Shabica & Associates. Review of Erosion Control Features for Interim Remedial Action Landfills 6 & 7, Fort Sheridan, Illinois, 11/25/97
[48] Responsiveness Summary, Proposed Remedial Action Plan for the Interim Action at Landfills 6 and 7, 124/22/97, Response 12-7 Pg. RSR-40

most recent shore-protective works that have been in place only for a few years."[49] The fact that the Army plans to excavate if things don't work out is nothing more than an admission that this remedy lacks permanence.

While the Army response to public comments argues that it does expect some bluff recession, per the requirement of the USGS study, in fact the only recession accepted in the analysis is to the adjacent bluffs. This is misdirection because the plain meaning of the study's conclusion is that each section of bluff should assume recession.

The degradation of shore protection armoring over a thirty-year period is addressed in a broader Great Lakes coastal erosion guidance document issued in 2003 jointly by the US Army Corps of Engineers and the Sea Grant at the University of Wisconsin entitled *Living on the Coast, Protecting Investments in Shore Property on the Great Lakes.* The lack of permanence and expense of armoring is one reason the principle message is to "[d]o everything possible to avoid placing buildings and other structures where flooding, storm waves, and erosion are likely to damage them or shorten their useful lives."[50]. Even more significant is that in replacing the *Help Yourself* booklet (1978) the message changes from the promotion of shore protection structures to the useful-life construction setback concept.[51]

Some of the conclusions of this study are that the high and low record lake levels which affect erosion rates could be significantly exceeded in the future[52]; a bluff edge that has been dormant for 40 years may lose 5

[49] Jibson, Randall W and Odum, Jackson K. *Rates and Processes of Bluff Recession Along the Lake Michigan Shoreline in Illinois.* U.S. Geological Survey, Denver, Colorado, 1994. Pg. 149
[50] U.S. Army Corps of Engineers, Detroit District and University of Wisconsin Sea Grant Institute. *Living on the Coast.* 2003. Pg. 1
[51] Id.
[52] Id. At 3

to 50 feet, or more, next week[53]; "using constructed shore protection to gain a close-up view of the lake is problematic and costly"[54]; "setback distances for buildings on properties with existing or planned shore protection structures should be estimated as if the shore protection structures were not present. Shore protection can fail-sometimes quickly and catastrophically. When this happens, the previously protected shoreline tends to recede rapidly toward the position of neighboring unprotected shorelines, erasing the benefits gained by the former shore protection structure"[55]; "breakwaters that have been well designed, well constructed, and properly maintained, a 25-year design life can be achieved, and in some cases the structure can function as long as 50 years"[56]; "shore protection structures are controversial and can impact the shore in undesirable ways" including a limited ability to predict impacts on other shoreline property[57]; a rule of thumb is that the average annual inspection, maintenance, and repair cost for armor stone shore protection is 2 to 5 percent of the original construction cost[58].

Further, the study defines the kinds of shore protection utilized at Landfill 7 as a moderation strategy intended to slow erosion. These include water management, making coastal slopes more stable, tripping storm waves, and paving the lakebed. "High lake levels, more frequent and stronger storms and storm waves will challenge a moderation strategy."[59]

On risk assessment the report concludes that the risk of damage comes from "close proximity to powerful natural forces that are not adequately

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[53] Id. At 12
[54] Id. At 15
[55] Id. At 16-17
[56] Id. At 28
[57] Id. At 29
[58] Id. At 36
[59] Id. At 21

understood and are not controllable."[60] "The practice of building close to the edges of erosive coastal slopes should be discouraged because it minimizes a natural buffer distance that is needed to keep risk management options open and to accommodate climate changes that are more extreme than the climate conditions encountered during the historical period of coastal settlement."[61] These conclusions by the Army Corps of Engineers are certainly at odds with the Army presumption that erosion at Landfill7 is fully controllable.

The Army Corps of Engineers produced another guidance document jointly with the Great Lakes Commission[62] in 1999 entitled, *Living With the Lakes: Understanding and Adapting to Great Lakes Water Level Changes.* The conclusion of this study is more absolute: "A variety of structural options are available to shore property owners to protect and stabilize bluffs and beaches vulnerable to the impacts of lake level fluctuations and storm events. The best structural option depends upon the site characteristics. Professional design consultation is advisable. None of these options, however, are permanent solutions against the continued and relentless forces of nature."[63] Relocation is desirable because it "recognizes that erosion and associated bluff recession is a natural process that, even with installation of structural protection, is difficult to stop entirely."[64] Relocation is "often more cost-effective and reliable in the long-term than most structural options."[65]

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60 Id. At 37
61 Id. At 39
62 US ACE and the Great Lakes Commission. *Living With the Lakes: Understanding and Adapting to Great Lakes Water Level Changes.* 1999 Pg 2. "The Great Lakes Commission is an eight-state compact agency established in 1955 to promote the orderly, integrated, and comprehensive development, use, and conservation of the water resources of the Great Lakes basin."
63 Id. at 34
64 Id. at 35
65 Id.

Legal challenges to remedies selected by the lead agency are normally given great court deference because the agency charged with administering those regulations is presumed to have the expertise to properly evaluate the remedy. *Chevron U.S.A. Inc. v. Natural Resources Defense Council, Inc.*, 467 U.S. 837, 843 (1984). Courts will therefore not overturn such a decision absent arbitrary and capricious decision-making. In the present case the Army is the lead agency. Because the Army is not tasked by congress with implementing CERCLA, and does not have the environmental expertise of US EPA, it is therefore not due such deference. If the courts were to find such expertise and grant such deference on the issue of coastal erosion, however, the Army's failure to follow the findings of its own studies certainly qualifies as arbitrary and capricious.

In yet another study of coastal erosion, mandated by Section 577 of the National Flood Insurance Reform Act of 1994 (Public Law 103-325), FEMA contracted with the Heinz Center to produce *Evaluation of Erosion Hazards*, [66]a study of the U.S. ocean and Great Lakes shorelines. The focus of this study was to evaluate the choices that public officials and private individuals face regarding shoreline erosion and federal insurance available through the National Flood Insurance Program (NFIP). One finding of the study is that relocation away from the shore is the only viable option for protecting structures already built.[67] In discussing if property owners should get a rate reduction for shoreline protection, "Congress still may want FEMA to ignore the presence or absence of beach nourishment when setting rates, or at least offer only modest rate reductions. Nourishment does not, after all, permanently alter erosion rates."[68]

[66] The H. John Heinz III Center for Science, Economics and the Environment, *Evaluation of Erosion Hazards*. April 2000

[67] Id. at 176

[68] Id. at 177

Dr. Shabica is both a coastal process expert and president of his company, Shabica & Associates, that designs and sells coastal protection projects. Shabica & Associates' breakwater erosion control system has been sold to multiple property owners along Lake Michigan over the last 15 years. The question must be asked, is Dr. Shabica's claim that his system will last 30+ years based on scientific evidence or is it merely sales marketing? Is 30+ years of shore protection a fact or an opinion? Is it guaranteed by Shabica & Associates? Did the Army take into account the implicit conflict of interest between Dr. Shabica's experience as a coastal erosion expert and his profit motive in selling the Army an expensive system that he has promoted to other high value property owners?

Dr. Shabica evaluated the Army's proposed design during the design review phase, after the containment remedy was already selected (and assumed to be protective of human health and the environment). He concluded that the proposed containment engineering on the bluff face would fail to prevent coastal erosion and proposed that his company engineer a breakwater system. In the proposal it was claimed this system would protect Landfill 7 for 30+ years. Shabica & Associates was then awarded the contract for $1.6 million. The question must also be asked if the Army was objective in evaluating Dr. Shabica's claims of 30+ years when 1) it apparently could not even evaluate its own design and 2) was now under pressure to implement some new plan after being told the old one would fail.

In conclusion, because 30 years is not the basis upon which to evaluate long-term effectiveness under CERCLA and because the geologic literature overwhelmingly holds that armoring of the shoreline will fail in the long-term, the containment remedy should be rejected.

3.3.4.2.1.2 RELOCATION Relocation of the waste to a properly planned and permitted landfill will fulfill the requirement that the remedy be effective in the long-term and permanent. Under this remedy, the waste will be excavated and characterized pursuant to SW846, Section 9 (USEPA, 1986).[69] Solid waste will go to a municipal waste landfill. Hazardous waste will go to a landfill permitted to accept such waste. Any waste that is characterized as so hazardous to trigger land disposal restrictions will be incinerated and then transferred to a permitted hazardous waste landfill. Once removed from the coast of Lake Michigan and relocated to each receiving landfill the remedy will require no further action. Each receiving landfill, while outside the required analysis, will also require no further action.

3.3.4.2.1.3 COMPARATIVE ANALYSIS Relocation of the waste away from the eroding coast of Lake Michigan is the only remedy that satisfies the long-term effectiveness and permanence criteria. The no action alternative is made moot by the fact that the containment remedy has been implemented and is therefore not part of this analysis.

The only remaining remedies are containment and relocation. The various guidance documents and statutory requirements for coastal construction along the shore of Lake Michigan are summarized in Table 2 and evaluated against the FS remedies. The Army's position that containment through shoreline engineering is a permanent and effective remedy is at direct odds with the Army's position through Army Corps of Engineers guidance documents on shoreline erosion.

The two cited Army Corps of Engineers guidance documents came out in 1999 and 2003, after the interim remedy was already chosen in 1997. The interim remedy finding of permanence and effectiveness for containment might therefore have been a closer call. In 2007, however,

[69] *Fort Sheridan Landfills 6 & 7-Final Focused Feasibility Study* 1996 Pg 218

such a finding of permanence and effectiveness is arbitrary and capricious because the Army is taking two opposite positions on the same subject. The Army Corps of Engineers position is the correct one while the Landfill 7 position is simply self-serving to avoid implementing a remedy that is more difficult and costly, yet required by geologic instability.

Table 2

Guidance Document/ Regulation	Findings and Recommendations, or Actions Required by Regulation	Are Recommendations or Requirements Modified of Waived Based on Shoreline Engineering?
Jibson, Randall W and Odum, Jackson K. ***Rates and Processes of Bluff Recession Along the Lake Michigan Shoreline in Illinois.*** U.S. Geological Survey, Denver, Colorado, 1994	• Shore protective devices had no detectable effect on recession rates • Temporal and spatial differences existing between adjacent bluff segments give way over longer periods of time because the bluffs erode in an overall parallel manner. • The anticipated life of structures near the bluff should be assessed for erosion over a 50 to 100 year time frame. • Any construction along the coast expected to last 100 years should be set back a minimum 65 to 80 feet	No
U.S. Army Corps of Engineers, Detroit District and University of Wisconsin Sea Grant Institute. ***Living on the Coast: Protecting Investments in Shore Property on the Great Lakes***. 2003	• "The practice of building close to the edges of erosive coastal slopes should be discouraged because it minimizes a natural buffer distance...needed to...accommodate climate changes that are more extreme than the...historical period of coastal settlement." • "setback distances...on properties with existing or planned shore protection structures should be estimated as if the shore protection structures were not present. Shore protection can fail-sometimes quickly and catastrophically. When this happens, the previously protected shoreline tends to recede rapidly toward the position of neighboring unprotected shorelines, erasing the benefits gained by the former shore protection structure"	No
U.S. Army Corps of Engineers, Detroit District and The Great Lakes Commission. ***Living With the Lakes: Understanding and Adapting to Great Lakes Water Level Changes***. 1999	"A variety of structural options are available to shore property owners to protect and stabilize bluffs and beaches vulnerable to the impacts of lake level fluctuations and storm events. The best structural option depends upon the site characteristics. Professional design consultation is advisable. None of these options, however, are permanent solutions against the continued and relentless forces of nature." Pg. 34	No

The Heinz Center under FEMA contract. (Mandated by Section 577 of the National Flood Insurance Reform Act of 1994 (Public Law 103-325), ***Evaluation of Erosion Hazards*** April 2000	• Relocation away from the shore is the only viable option for protecting structures already built. • In discussing if property owners should get a rate reduction for shoreline protection, "Congress still may want FEMA to ignore the presence or absence of beach nourishment when setting rates, or at least offer only modest rate reductions. Nourishment does not, after all, permanently alter erosion rates." Pg. 176	No
City of Highland Park. ***Living in a Ravine and Lakefront Community.***	"Water erosion is the most threatening force impacting ravine and lakefront property. It is a natural force which can be slowed, but cannot be stopped entirely."	No
National Flood Insurance Program ***Requirements for Insurability of Coastal Structures***	• Community participation in the NFIP requires, "a setback for all new development from the…lake…, to create a safety buffer….This buffer will be designated…according to the flood-related erosion hazard and erosion rate, in conjunction with the anticipated 'useful life' of structures…."44 C.F.R. 60.5 • Zone of imminent collapse means an area subject to erosion adjacent to the shoreline of an ocean, bay, or lake and within a distance equal to 10 feet plus 5 times the average annual long-term erosion rate for the site…" 44 C.F.R. 59.1	No
City of Highland Park Zoning Ordinance. ***Sec. 150 Article XIX Steep Slope Zone***	• "…land should support new structures for a minimum of fifty (50) years…"Sec. 150.1902(A)(3) • "The Steep Slope Zone includes…a 40' setback from the top of a lake bluff slope." Special Permit Requirements for Ravine and Lake Bluff Property and Other Steeply Sloping Lots in Highland Park • "…No structures shall be constructed in a Steep Slope Zone." Sec. 150.1903(A)	No
City of Lake Forest ***Sec. 46-15. Steep Slope Ordinance***	"All building construction shall be on tableland, but in no case shall a structure or building foundation be located closer than seventy-five (75) feet to the bluff area." Sec. 46-15(C)(1)(b) Building Setbacks From Bluffs	Maybe. "Variation from any restriction could be recommended if the…bluff slope does not show any indication of instability…"Sec. 46-15(D)(d)

3.3.4.2.2 **4. REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT**

3.3.4.2.2.1 <u>CONTAINMENT</u> There are downward pathways unaccounted for in the Army's analysis. See Appendix I. Additionally, the Army analysis of groundwater infiltration is flawed and new leachate will continue to be created over time. See Comment 2.1.

3.3.4.2.2.2 <u>RELOCATION</u> Relocation reduces mobility because the groundwater pathways cannot be fully accounted for, given the unique geology of the ravine/bluff environment.

3.3.4.2.2.3 <u>COMPARATIVE ANALYSIS</u> The Army improperly attributes greater mobility to the relocation remedy in the FS because the waste is being excavated and moved. Mobility during transport is not the mobility evaluated under CERCLA but rather the mobility of the waste in the environment through natural process. The moving of hazardous waste is presumed to be safe through the use of known shipping methods by which all kinds of hazardous chemicals travel everyday. The Army arbitrarily evaluates hypothetical catastrophic shipping failure while never evaluating catastrophic bluff failure in the containment analysis for the feasibility study. Mobility is more properly compared between containment in a ravine geology and relocation to a properly planned landfill with a high density bottom liner. The containment strategy does not reduce mobility through catastrophic bluff failure whereas relocation presumptively reduces mobility because modern sanitary landfill standards are used in the receiving landfill.

3.3.4.2.3 5. SHORT-TERM EFFECTIVENESS

3.3.4.2.3.1 <u>CONTAINMENT</u> In the short term, containment suffers from leachate creation through groundwater flows (See Comment 2.1), failure to account for all migratory pathways (see Appendix A), and failure in properly implement to landfill cap by using unscreened soils (See Exhibit EPA).

3.3.4.2.3.2 RELOCATION While there are short-term effectiveness risks to relocation, even the Army admits, "[e]ngineered controls such as enclosures with air treatment systems (e.g., carbon adsorption) are reliable."[70] The Army goes into great detail about the 26,450 truckloads of waste, one every 20 minutes for 3.5 years, and the potential for accidents and public opposition.[71] Transportation of hazardous waste happens everyday without incident. Further, this volume of waste hauling is not significantly greater than waste disposal activities already occurring in the area.[72]

Short-term effectiveness is certainly the biggest concern of the nine criteria for the relocation remedy but potential risks will be minimized through monitoring and adequate safety planning.

3.3.4.2.3.3 COMPARATIVE ANALYSIS This criterion only deals with effectiveness during the implementation phase. Containment is therefore more effective in the short-term than relocation because the containment remedy is already in place as part of the interim remedy. Additionally, relocation involves exposure of the waste to the atmosphere that is a danger to workers and the community. The risk, however, is manageable. Further, the risk is justified under any waste scenario because as the toxicity of the waste increases, and therefore the danger in excavation, so too does the risk of containment failure in proximity to Lake Michigan. The risks are not equal, however, because truck safety can be managed with careful planning and exposure can be managed by enclosure whereas mitigation of shoreline erosion is at the mercy of violent forces of nature.

[70] *Fort Sheridan Landfills 6 & 7-Final Focused Feasibility Study* 1996 Pg 227

[71] Id. at 221, 225, 226, 233, and 238

[72] Hayes, Jeff, employee, Onyx Waste. Phone conversation. Fourteen residential garbage trucks operate on a daily basis in Highland Park (as compared to the estimated 30 trucks making one way trips in and out of town for the relocation remedy) hauling 250cy of household/recycling waste per day (as compared to 600cy proposed in the relocation remedy). July 22, 2004

3.3.4.2.4 6. IMPLEMENTABILITY

3.3.4.2.4.1 CONTAINMENT – Implementation was flawed and is not protective of human health and the environment. See Exhibits M, N, and O To the extent that changes must be made to bring the containment remedy up to the standards of the interim decision document and design document, implementation is difficult because the carefully planned layers of the cap must be completely excavated and reimplemented, almost from scratch.

3.3.4.2.4.2 RELOCATION – Excavation is difficult to implement because the unknown character of the waste requires identification and separation but as explained in Comment 3.3.4.2.3 on Short Term Effectiveness, it is not impossible.

3.3.4.2.4.3 COMPARATIVE ANALYSIS – Implementability is equally difficult between both alternatives once the Army recognizes that the cap, as implemented, must be deconstructed because of the deviations introduced during implementation.

3.3.4.2.5 7. COST This criterion assesses capital cost as well as operation and maintenance costs using the NPV of each.[73]

3.3.4.2.5.1 CONTAINMENT The army underestimated the costs in the containment analysis. Cap replacement costs and flanking erosion protection were all left out. In response to public comment 17.1 the Army uses the discount rate to justify a preference for expenditures drawn out well into the future such as will be necessary for containment rather than the upfront costs associated with immediate excavation.[74] This misstates the proper use of discounting by applying current costs to future projects and discounting back to the present. The Army has a duty to assess future expenditures at future costs prior to discounting to the present. *State of Ohio v. U.S. Dept. of the Interior*, 880 F.2d 432, 464-

[73] 40 C.F.R. § 300.430(e)(9)(iii)(G)

[74] Responsiveness Summary, Proposed Remedial Action Plan for the Interim Action at Landfills 6 and 7, 124/22/97, Response 17.1 Pg. RSR-47 "It should be recognized that the present worth of expenditures for repairs 30 years in the future is approximately 13 percent of the future cost assuming a 7 percent discount rate (e.g., a $3 million expenditure 30 years from now for cap repairs has a present worth of only approximately $394,000 based on 7%).

465(C.A.D.C.,1989)[75] Therefore, inflation would cause a $3 million expenditure today to cost $22.8 million in thirty years based on the 7% discount rate. (it could be argued that landfill construction costs will rise faster or slower than the general inflation rate) It would take $3 million, set aside and invested today, to pay for the repair in thirty years and that is the proper use of the discount rate. Without setting aside the money then the cost of the cap in 30 years is the price today plus inflation. If the Army then wants to discount it back to today the price is an additional $3 million. Applying this reasoning to the entire cap, the Army underestimated the cost of the cap plus replacement by a full 50% of the total price.

While recognizing that a major cap repair is possible, the Army counters that such an activity is dissimilar to the original cap construction because many of the original materials are already present.[76] It is impossible to reconcile this statement with the FS analysis of implementability stating "[f]urther remedial action at the site would be difficult due to the complex stratification of the landfill cover. Dismantling of the landfill final cover, component by component, without damaging underlying components, would be extremely difficult, if not impossible."[77]

Because the cap has a useful life of 30 years, $17 million of today's money or $129 million at future prices, will again be spent in 30 years. It

[75] "If a release of hazardous substances will necessitate a restoration project costing *x* dollars five years from now, CERCLA requires that the responsible party pay a sum sufficient to cover those costs *at that time.* Due to the inherent time-value of money (coupled with the effects of inflation), an amount significantly less than *x* dollars invested today will yield CERCLA's required *x* dollars at the time the restoration costs are incurred five years from now. Using the proper interest rate as a discount rate, it is possible to calculate how much money must be collected today to equal *x* dollars in the future. The danger of undervaluation arises from an underestimate of the *future* cost of restoration or from an incorrect discount rate, not from the basic process of discounting itself." *State of Ohio v. U.S. Dept. of the Interior* 880 F.2d 432, 464-465(C.A.D.C.,1989)

[76] Responsiveness Summary, Proposed Remedial Action Plan for the Interim Action at Landfills 6 and 7, 124/22/97, Response 17.1 Pg. RSR-47

[77] *Fort Sheridan Landfills 6 & 7-Final Focused Feasibility Study* 1996 Pg 217

is also difficult to reconcile how the proposed patchwork of lake side erosion controls, envisioned by the Army to address flanking erosion, can be easily tied into the complex landfill cover. The entire geometry of the landfill changes with flanking erosion and no extra synthetic material was left to be "let out" as more surface area needs to be covered. This represents a major undertaking that will probably require complete cap reconstruction. It was arbitrary and capricious to leave these costs out of the containment remedy because cap replacement and/or major modification are foreseeable.

3.3.4.2.5.2 RELOCATION The cost analysis of excavation is virtually useless without characterizing the waste. The Army continuously argued throughout the responses to public comments that further characterization was not called for. The reasoning was that the waste was assumed to be special waste typical of MSWLF's for which containment offers presumptive and adequate protection. The problem is that when the uncharacterized waste is excavated it must be sorted based on toxicity. Depending on the toxicity it might go to another MSW landfill, to a hazardous waste landfill, or might trigger land disposal restrictions and require incineration prior to placement in a hazardous waste landfill. The Army gave equal weight to the range of possible waste characterizations and used the variability in costs and uncertainty to guide the assessment towards the preferred containment remedy.

The risks associated with containment under the three waste scenarios are not equal, however, unless one disregards the risk of catastrophic cap failure due to erosion. As stated the Army operated on the assumption that containment would work. If one considers containment failure, however, then the increasing toxicity of the waste increases the risk of the containment remedy. The Army is obligated to assess this risk.[78]

[78] 40 C.F.R. § 300.430(e)(9)(iii)(C)(1)(2)

Therefore, as the cost of relocation goes up with higher toxicity, so does the corollary risk of containing the increasingly toxic waste along Lake Michigan. At the lower toxicity levels the cost of relocation becomes comparable to the long-term costs of containment.

3.3.4.2.5.3 COMPARATIVE ANALYSIS Because the Army underestimated the containment costs while overemphasizing the uncertainty and variability of relocation costs without addressing the risks represented by the variability in costs, the FS did not convey an accurate comparison of the remedies. If the waste was known to be so hazardous as to trigger land disposal restrictions then serious consideration would have to be given to spending $711 million for relocation rather than engineering the landfill against coastal erosion 1 ½ miles updrift of two municipal water supply intake cribs serving over 60,000 residents.

3.3.4.3 MODIFYING CRITERIA

3.3.4.3.1 8. STATE ACCEPTANCE - This criterion assesses the state concerns with the proposed remedy and cannot be completed until after comments are received.[79]

3.3.4.3.1.1 CONTAINMENT - The state appears to be in accord with the containment remedy.

3.3.4.3.1.2 RELOCATION - The state does not appear to favor relocation although it is not clear the state regulators have evaluated the recent geological literature regarding Great Lakes coastal erosion presented in detail in this comment. In the absence of US EPA participation the state has regulatory CERCLA oversight. This is in addition to the state's right to grant or deny state acceptance. The state, in its role as regulator, should realize that containment is not effective as required by CERCLA after reading these comments. The state should also withhold acceptance for purposes of this criterion as well.

[79] 40 C.F.R. § 300.430(e)(9)(iii)(H)

3.3.4.3.1.3 COMPARATIVE ANALYSIS - The state acceptance of remedies cannot be compared before the state has had a chance to read this comment and grasp the geological reality of containment.

3.3.4.3.2 9. PUBLIC ACCEPTANCE

3.3.4.3.2.1 CONTAINMENT – The public comments for the interim remedy overwhelmingly disfavored containment.

3.3.4.3.2.2 RELOCATION – The public comments for the interim remedy overwhelmingly favored excavation and relocation.

3.3.4.3.2.3 COMPARATIVE ANALYSIS – Very few people attended the public meeting for the final proposed remedy. In fact, I was the only member of the public to speak. I am against containment. My feeling is that substantial members of the public came our in 1996 against the containment remedy but most people misunderstand the nature of an interim action under CERCLA and assume the final decision was already made. That would explain the lack of attention now that the final remedy is being proposed. In any case, the public cannot be said to be for or against either remedy under this balancing criteria.

3.3.4.4 CONCLUSION - Relocation through excavation is clearly preferable to containment for almost all of the nine criterion including three of the most important; overall protection of human health and the environment, compliance with ARAR's, and permanence and long-term effectiveness. Relocation therefore represents the best, and only remedy to satisfy the various requirements, criterion, guidance documents, executive orders, and statutory law brought forth in these comments.

Appendix I

Fort Sheridan Landfill 6 & 7 Closure, Don Walsh and Polina Liberman, Department of Civil Engineering, Northwestern University, (2003)

Fort Sheridan Landfills 6 & 7 Closure

Prepared for
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i. EXECUTIVE SUMMARY

This report is submitted as public commentary on the proposed Final Remedy for Landfills 6& 7 at Fort Sheridan, which is essentially to make the Interim Remedy permanent. We have attempted to address possible causes for concern with the alternative proposed by the Army: leaving the waste in place and capping the landfills. Fort Sheridan was a U.S. Army base that was operated from the 1880's until 1993. The landfills were active for about 30 years and according to the Focused Feasibility Study prepared by accepted construction, industrial and domestic refuse. In 1982 an initial cap was placed on the landfill. This cap did not perform adequately and so the Army set about designing a new plan during the 1990's. They considered both capping and excavating the landfill. They eventually choose the capping alternative for cost and practicality reasons. The Army's design had many features, including a RCRA equivalent cap, perimeter storm drain, leachate collection drain and interception trench and a gas recovery and treatment system.

One item that the interim plan did not adequately address was the possibility that shoreline erosion could impact the portion of the landfill near Lake Michigan. We found that the Army vastly underestimated the danger of erosion of the bluff both via wave action and runoff from above. This is particularly worrisome because historic geological data has shown that there is little that engineering can do to slow the rate of bluff erosion. To address these concerns, we recommend that the Army thoroughly characterize the waste to assess the danger, consider the cost of replacing the cap due to erosion, add additional erosion protection and establish a scenario if excavation were to become necessary.

ii. ACKNOWLEDGEMENTS

We would like to thank Professors Kimberly Gray and Robert Gemmell for providing us with the opportunity to participate in the Service Learning Program, as well as for their essential guidance and assistance throughout the course of the project. We would also like to thank Keith Harley, of the Chicago Legal Clinic, for entrusting us with this project and for providing useful and pertinent information. Additionally, we would like to thank Steven Pollack, for being a passionate participant and an avid activist, and for providing us with countless helpful resources which aided our research tremendously. Additionally, we would like to acknowledge the assistance of Charles Norris, of Geo-Hydro, Inc for his crucial consultation, and Owen Thompson, the Fort Sheridan Environmental Coordinator, for assisting us with our research at the Fort Sheridan Repository.

1. INTRODUCTION

Fort Sheridan Army Base, located 20 miles north of Chicago on the shore of Lake Michigan, was closed in May 1993 under the Base Realignment and Closure Act of 1988. Since the time of the base closure more than half of the land has been cleaned up and transferred to surrounding communities for residential development. The rest of approximately 300 acres was transferred to the U.S. Navy and the U.S. Army Reserve. The Army continues to be responsible for the ongoing remediation efforts at the site. Their main focus are the two unlined landfills, 6 & 7, which operated between 1940' s and 1979 and were classified as Municipal Solid Waste (MSW) since the base closure, but present a special case, due to the high uncertainties regarding their contents and their close proximity to a major drinking water source, Lake Michigan.

This report was written in order to address the concerns raised by some members of the neighboring communities with respect to the Army' s plan to cap the two landfills and implement leachate and gas collection systems. The proximity of the landfills, particularly Lanfill 7, to Lake Michigan and the vast uncertainty with respect to the potential presence of hazardous materials cause great potential for concern. Also important is the fact that the landfills are located on a bluff which has been shown to be unstable and susceptible to erosion according to USGS studies performed in the 1990' s.

In order to address the concerns raised by Steven Pollack, a member of the Highland Park community, on how the capping alternative was concluded to be the most effective action in satisfying all applicable or relevant and appropriate requirements (ARARs), Keith Harley of the Chicago Legal Clinic raised the following questions:

- Does the expected final remedy as implemented in the form of capping for the interim action satisfy all the ARARs?
- Will the measures taken by the Army as part of the interim action protect the contents of the landfill from being exposed to Lake Michigan waters?
- Will the Army' s expected final remedy fulfill its role for the expected life of the landfill?
- What other components of the interim action are cause for concern?
- If the interim action is implemented as the final remedy, what possible future conditions might trigger the necessity to excavate Landfills 6 & 7?

This report studies these questions in the attempt to evaluate the Army' s decision to cap the landfill as the final solution for dealing with Landfills 6 & 7.

2. BACKGROUND

Fort Sheridan is located near Highland Park, Illinois, about 20 miles north of downtown Chicago (Figure 1). It is bordered to the south by Highland Park, to the west by the Town of Highwood, to the north by Lake Forest and to the East by Lake Michigan. The Fort was originally a 712 acre U.S. Army installation that was in operation from 1887 to 1993. The Fort was officially decommissioned in 1993. 206 acres were transferred to the U.S. Navy for use as military housing. 100 acres were retained by the U.S. Army Reserve for equipment, training and administrative purposes. The remaining 400 acres were transferred to municipal control and are now being developed as single and multi-family housing.

The locations of Landfills 6 & 7 are shown in Figure 2. The landfills are in the southern portion of the base in what was formerly Wells Ravine. The landfills are located on U.S. Army Reserve and U.S. Navy property and are surrounded by family housing, a playground and various administrative buildings. Figure 3 shows the current use of the former base. The landfills were created between the 1940's and the 1970's by filling the 3000 foot long Wells Ravine with refuse. Prior to placing waste material in Wells Ravine, a storm drain was installed along the bottom of the ravine. The drain runs along the bottom of Landfills 6 & 7 and is overlain by the waste materials that were placed in both landfills. The drain was originally designed to handle drainage of the entire 120 acre Wells Ravine watershed.

The geology of the area is described as glacial till which is part of the Wadsworth Till Member. This Member is generally ranges in textural composition from clay to sandy clayey silt. The till in the area of Wells Ravine appears to be typical of the area. Included in the area are sand and gravel zones that are narrow and discontinuous.

The Focused Feasibility Study prepared by Civil & Environmental Engineering, Inc. states that the waste disposed of in these landfills is a mixture of construction, industrial and domestic refuse. Specifically, according to a 1989 study, wastes in these landfills include waste oil, solvents, paint products, and carbon cleaning products, sewage treatment plant sludge, hospital & veterinary waste, ammunition boxes and incinerator and heating plant ash. Records also indicate that radioactive components were discarded in the Landfills from previous activity associated with the Nike missile defense system at Fort Sheridan. However, it's reasonable to believe that insufficient efforts have been made to classify the waste, and thus, the authors of this report do not consider the knowledge concerning the contents of the landfills to be adequate. Landfill 6 is believed to contain a higher percentage of construction debris, but reportedly also contains some domestic industrial waste. Based on available information, Landfill 6 contains approximately 60,000 to 70,000 cubic yards of waste, while Landfill 7 contains approximately 400,000-460,000 cubic yards of waste. The landfills expanded over time until at closure, Landfill 7 covered approximately 7.7 acres while Landfill 6 covered approximately 3.3 acres. An aerial photo of the Landfills is provided in Figure 4.

Figure 1: Site Location

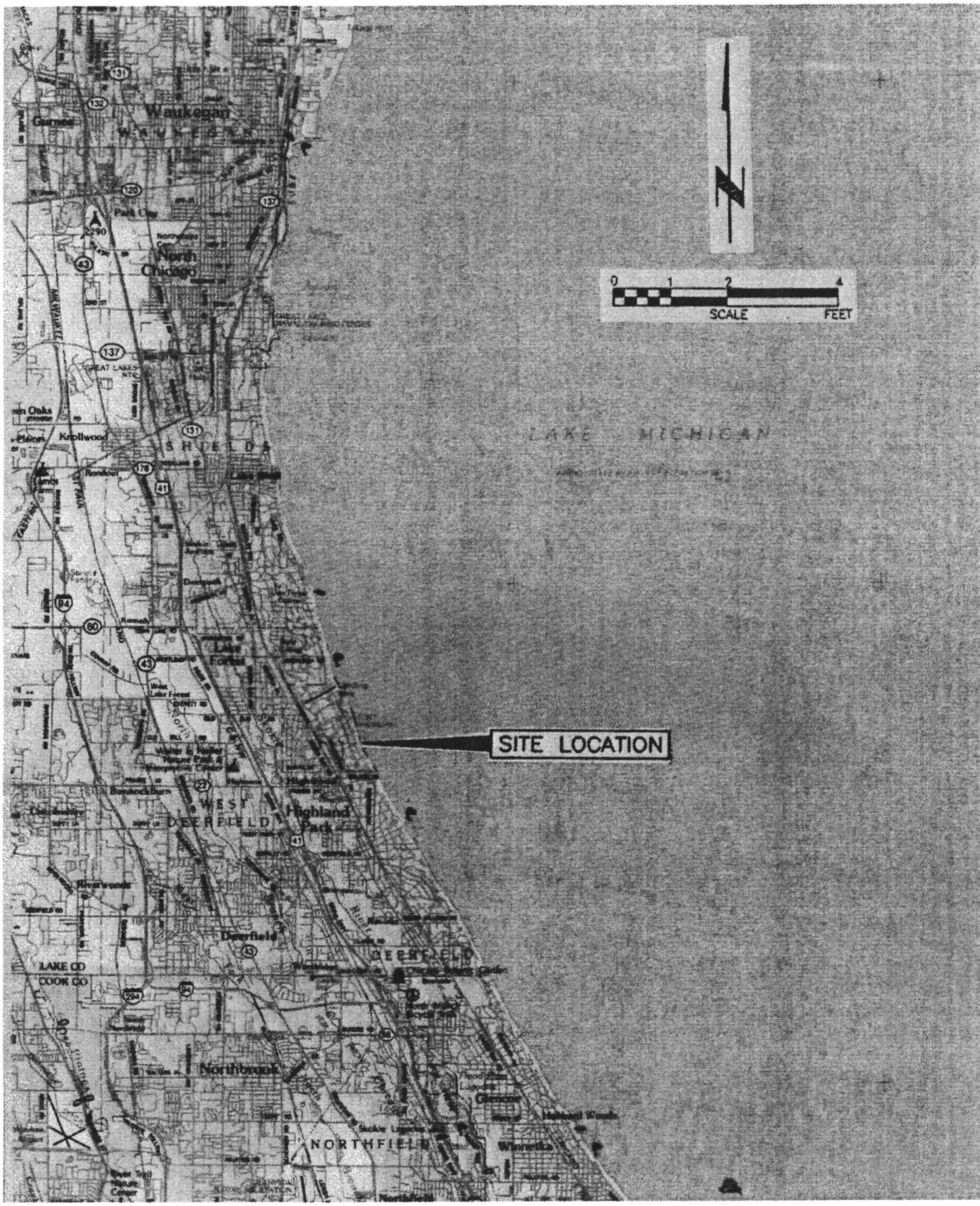


Figure 2: Site Vicinity

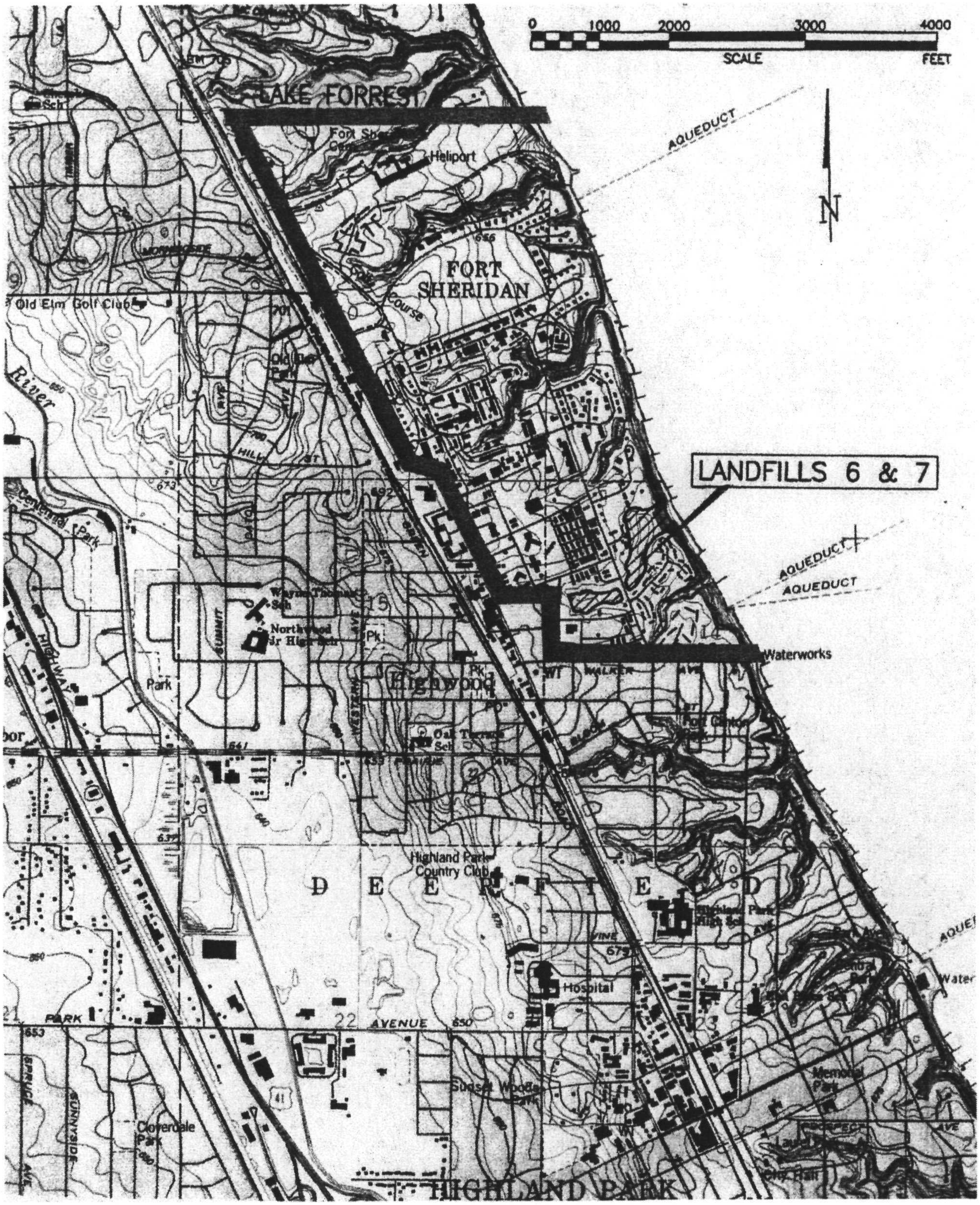


Figure 3: Current Fort Sheridan Land Use

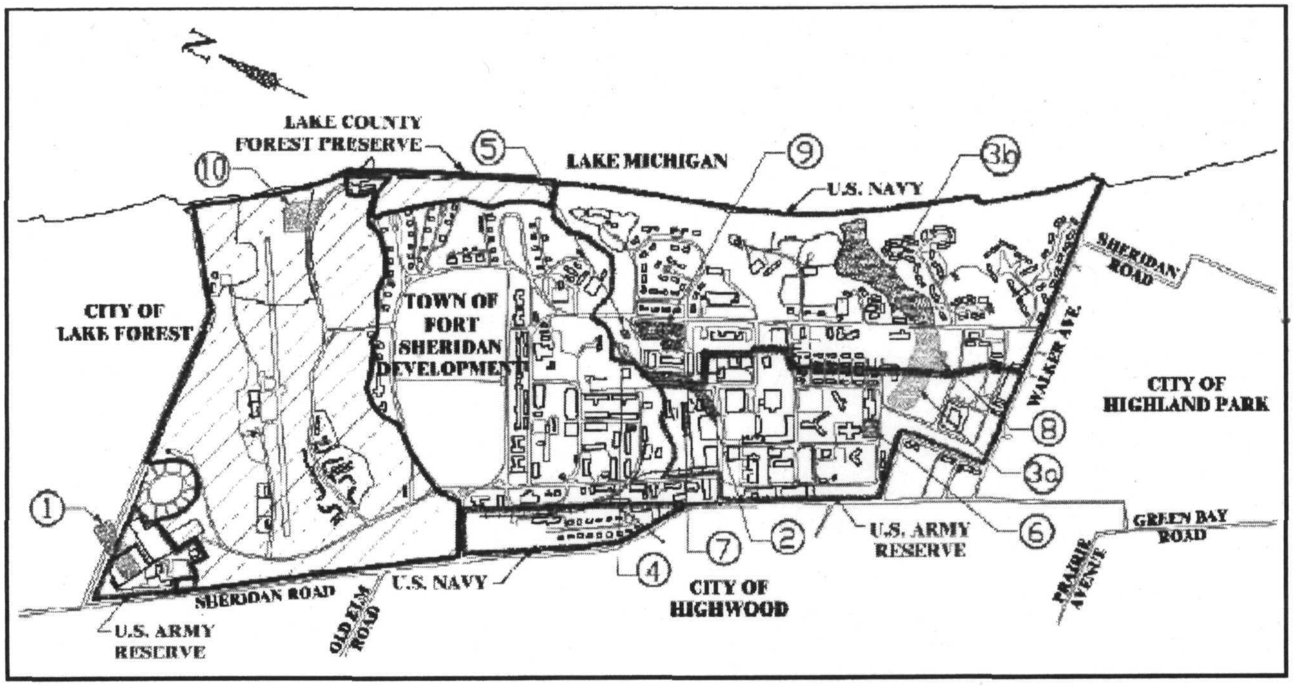


Figure 4: Aerial Photo Landfills 6 & 7

KEY:

1	Landfill 1
2	Landfill 5
3a	Landfill 6
3b	Landfill 7
4	Coal Storage Area (CSA) 3
5	CSA 4
6	Water Tower
7	Building 70
8	Vehicle Equipment Storage (VES) Area 8
9	Building 208
10	Landfill 2

2.1 1982 Landfill Closure

The landfill stopped accepting refuse in 1976. In 1982, a first attempt was made to close the landfill and cap it in order to isolate its contents from the environment. The components of the cap were as follows:

1. A soil cover was placed on the landfills
2. Vents were constructed to allow for release of gas from the landfill
3. A leachate interception trench was built between Landfill 7 and Lake Michigan
4. Storm drains were installed around the landfill perimeter to collect runoff
5.

The soil cover was designed to be 24 inches thick. Subsequent testing has shown that soil cover is generally 20-42 inches thick, with a few areas covered with as little as 2 inches. The soil in this initial cap consisted of soils ranging from silty sand to sandy clay.

Six passive gas vents, discharging to the atmosphere, were installed on Landfill 7 and two on Landfill 6.Testing of gas emissions from Landfills 6 & 7 indicate that the contents of the landfills are similar to those of municipal landfills. Organic constituents of the gas include methane, vinyl chloride, acetone, benzene, chloroform and carbon tetrachloride. The results of 1995 gas vent sampling can be found in Appendix I. The gas emitted from Landfill 7 is approximately 9.6% methane.

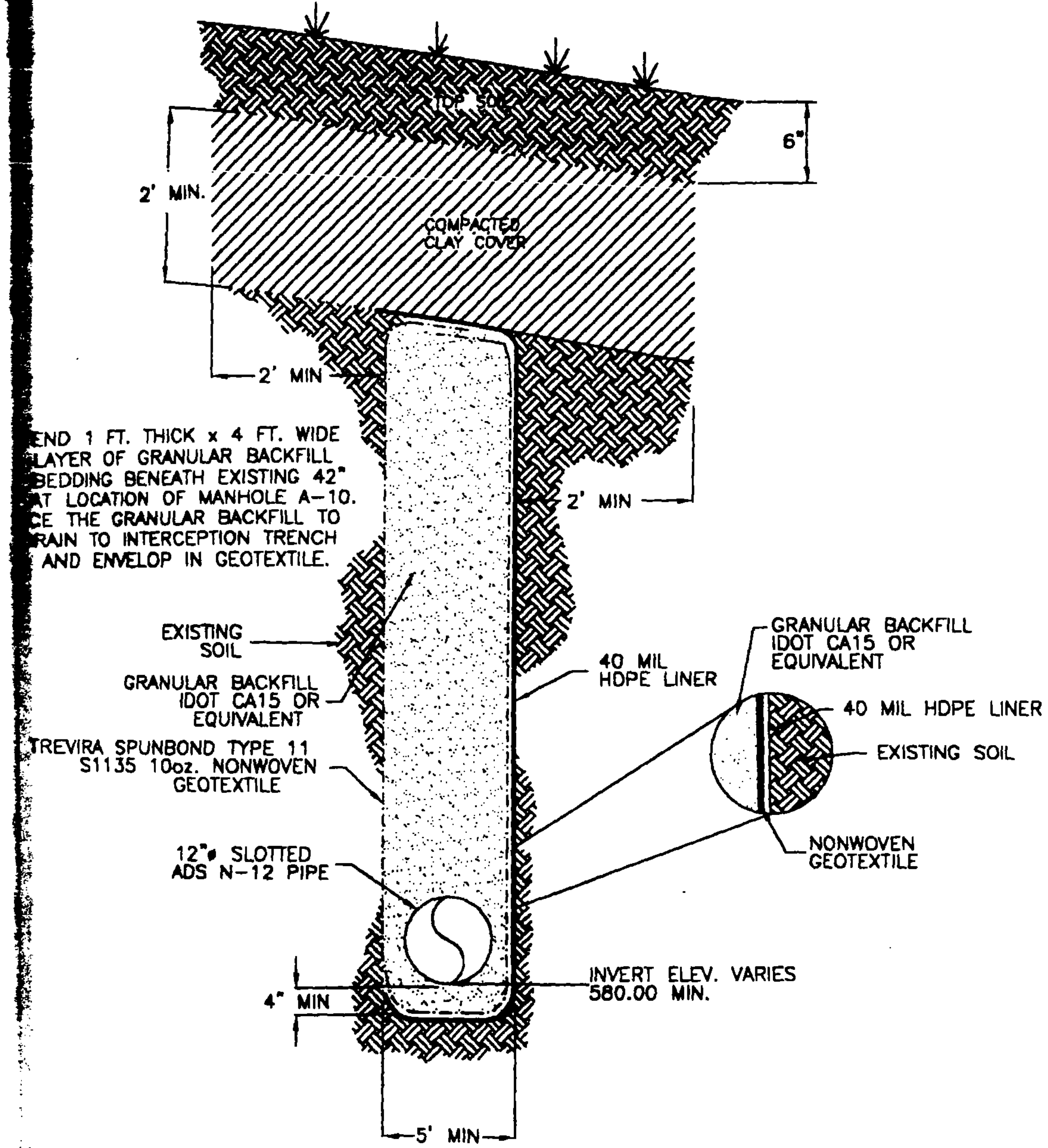
A diagram of the Leachate Interception Trench is shown in Figure 5. The trench is necessary in order to prevent leachate from flowing into Lake Michigan. The trench works as follows: leachate flowing toward the Lake enters a region of gravel designed to allow for easy drainage. The leachate then flows downward into a pipe running near the bottom of the trench. The leachate is then pumped out and disposed of. To prevent leachate from moving through the barrier, the lake ward side of the trench is lined with an impermeable membrane. The Trench is located near the toe of the East Face (the bluff which forms the boundary between Landfill 7 and Lake Michigan) just lake-ward of the edge of the approximate waste boundary. The location of the Trench and a detail view of the East Face are shown on Figure 6.

2.2 Problems with 1982 Closure

The initial closure of the landfills did not solve all of the environmental problems associated with the them. Most of the features installed under the 1982 closure did not perform adequately. The problems associated with some of these features present a good example of potential problems that could emerge once again if the cap were to ever fail in the future. The problems that the Army is trying to address with the current interim plan are as described in the following paragraphs.

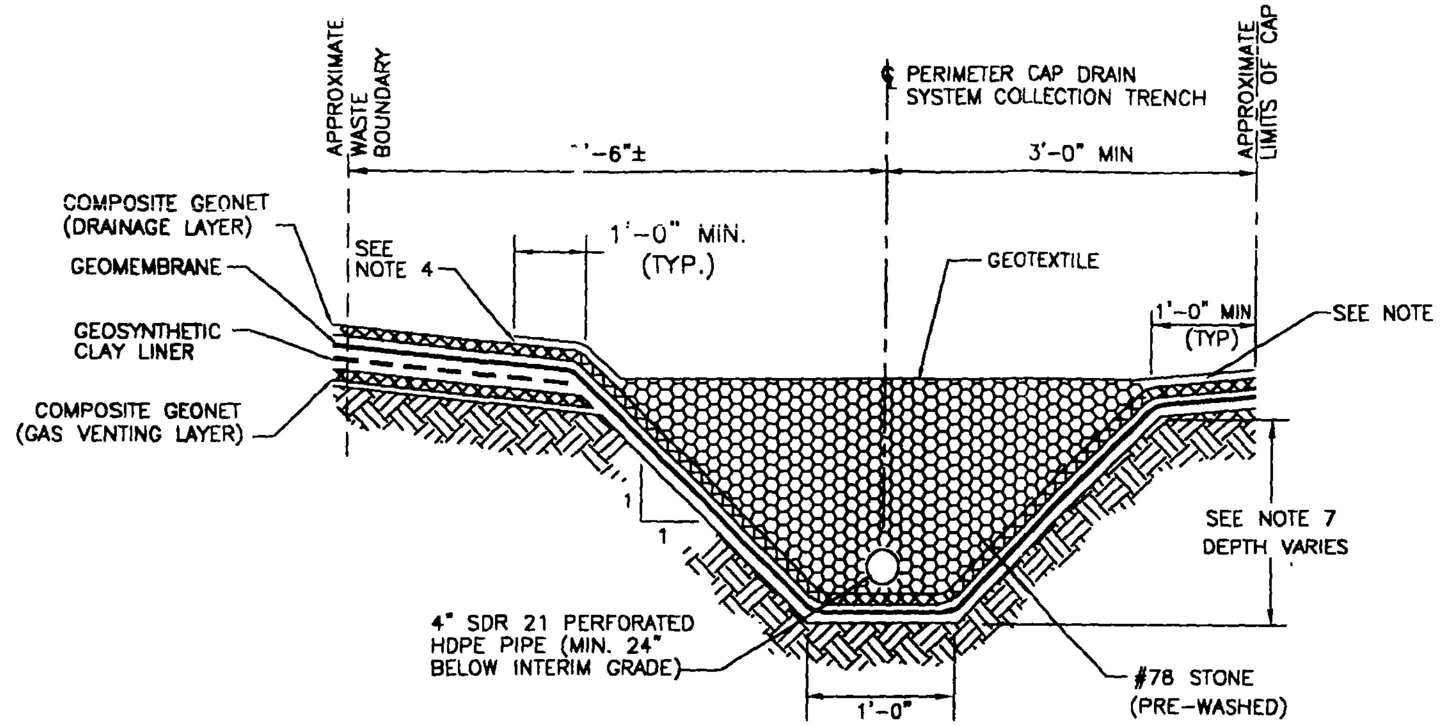
One failure of the initial cap was associated with the fact that leachate would occasionally seep out through the cap. This leachate would percolate to the surface and then flow outward in small rivulets. Most of these seeps would occur in the top of the cap, but more troubling, a significant portion would occur in the East Face. Seeps from the East Face would lead to the erosion of the cap and could possibly lead to cap failure. In one incident which occurred near the end of the 1982 closure construction, "an area of 20 to 25 feet directly up slope had sunk 8 to 12 inches··· The area was approximately 20 feed directly up slope from the new leachate pump station.' A thick, red liquid of syrup consistency apparently containing rust was running out of the slope."

Figure 5: Leachate Interception Trench and Cap System Details



1 EXISTING LEACHATE INTERCEPTION TRENCH TIE-IN
NTS

NOTE:
THIS DETAIL IS FOR REFERENCE ONLY, TO SHOW HOW THE EXISTING LEACHATE INTERCEPTION TRENCH WAS CONSTRUCTED. THIS DETAIL WAS TAKEN FROM THE AS-BUILT DRAWINGS (DECEMBER 2000).

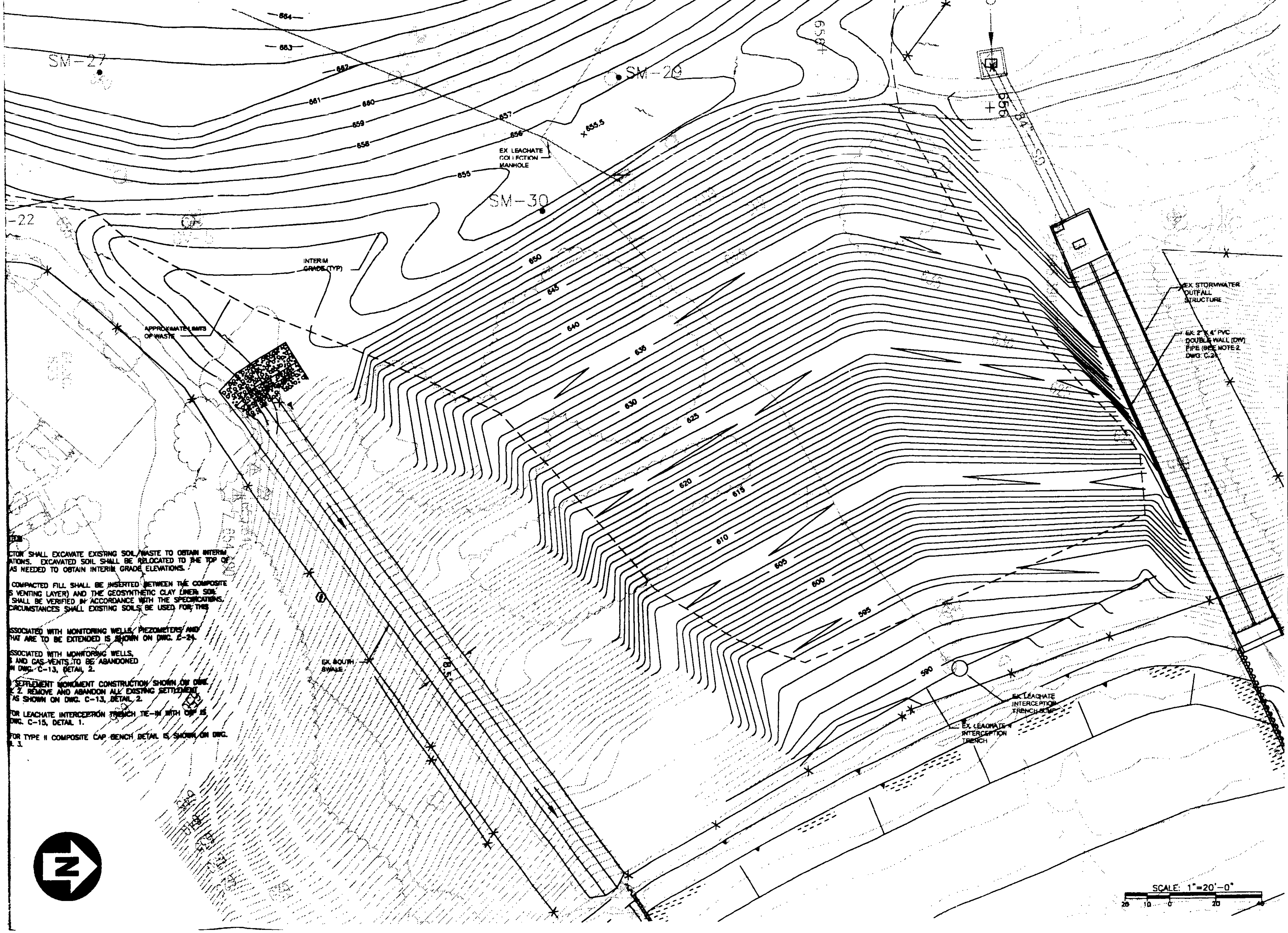


NOTES:

1. CONTRACTOR SHALL EXCAVATE TRENCH WITH 1 TO 1 SIDE SLOPE AND A 1 FOOT MINIMUM BASE WIDTH. THE CONTRACTOR SHALL SMOOTH, MANUALLY IF NECESSARY, THE SURFACE OF THE NOTCH REMOVING ALL MATERIAL DELETERIOUS (ROCKS, STICKS, ETC) TO THE GEOMEMBRANE LINER, PRIOR TO LAYING THE LINER ON THE SURFACE OF THE GROUND. THE CONTRACTOR SHALL FILL ALL VOIDS WITH SOIL TO ENSURE A SMOOTH, UNIFORM SOIL SURFACE PRIOR TO PLACEMENT OF THE GEOMEMBRANE.
2. CONTRACTOR SHALL THEN LAY THE 40 MIL GEOMEMBRANE ALONG TRENCH SIDE SLOPES AND BOTTOM, AS PER THE DRAWING.
3. CONTRACTOR SHALL THEN LAY THE NONWOVEN COMPOSITE GEONET OVER THE GEOMEMBRANE, AS SHOWN ON THE DRAWING.
4. AFTER PLACEMENT OF #78 WASHED STONE AND PIPING, THE CONTRACTOR SHALL PLACE THE GEOTEXTILE OVER THE STONE AND HEAT BOND THE GEOTEXTILE TO THE GEOTEXTILE OF COMPOSITE GEONET. HEAT BOND PER SPECIFICATIONS.
5. THE HEAT BONDING OF GEOTEXTILES WILL NOT TAKE PLACE DURING RAIN, WET, FROST OR FOGGY CONDITIONS.
6. THE GEOTEXTILE USED IN CONSTRUCTION OF THE TRENCH MUST BE THE SAME AS THAT USED IN THE COMPOSITE GEONET.
7. MINIMUM TRENCH DEPTH = 1'-0"
   MINIMUM STONE DEPTH = 1'-0"
   MAXIMUM STONE DEPTH = 2'-0"

2 TYPICAL PERIMETER CAP DRAIN DETAIL
NTS

Figure 6: Landfill 7 East Slope Interim Grading Plan



The efforts to control the release of gas were equally ineffective. One estimate put the amount of landfill gas that was vented through the passive vents at 20 percent.

Another problem with the 1982 closure concerned ponding on and near the landfill. Uneven grading on top of the cap led to small ponds of rainwater forming small ponds on the cap. Ponding also occurred along the perimeter of the cap, where water running off the cap would collect in depressed areas surrounding the landfill. The storm water collection methods in place were insufficient to prevent this problem. This is significant because ponding contributes to leachate generation, which can lead to the migration of contaminants from the landfill.

One final problem that was noted was the failure of the Leachate Interception Trench to collect leachate. It is believed that the phreatic surface (water table) is too low for the trench to collect leachate. Essentially, there is not enough leachate flowing toward the trench for the trench to operate.

This is not the end of this particular problem. Geotechnical studies done in 1991 show that the groundwater conditions on the beach between the Interception Trench and the Lake are artesian. This means that groundwater at depth in this area tends to rise to the surface. This is demonstrated in Figure 7, which shows that the groundwater is generally flowing from the landfill, under the trench and then up toward the surface. One should also note Figure 8, boring logs taken from the beach. This figure shows the condition of the beach in an axis perpendicular to the lake, with the right side near Landfill 7 and the left side near the lake. It shows a sandy layer on top to a depth of 577 feet and lenses (narrow layers) of high permeability soil below that. The elevation of the bottom of the Leachate Interception Trench is 580 feet, which is about the mean lake level. While, these conditions set up a possible situation where leachate flows underneath the trench (leaving the trench dry), through one of these high permeability layers and then up into the Lake, the issue warrants further investigation to ascertain why the Leachate Interception Trench does not appear to be functioning as would be expected.

F[illegible] e 7: Groundwater/Leachate Flow Net near LF7MW[illegible] nd LF7MW6D

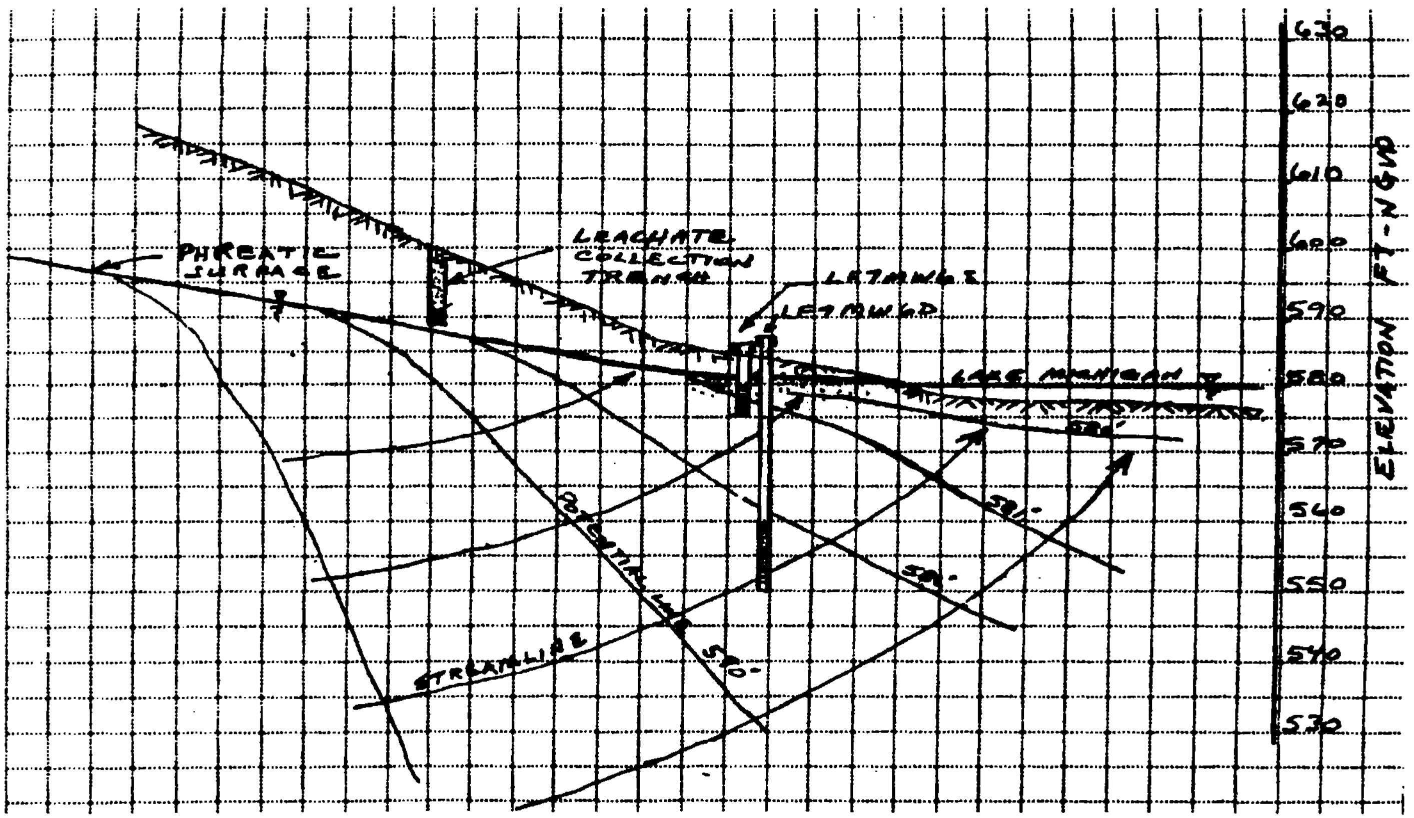
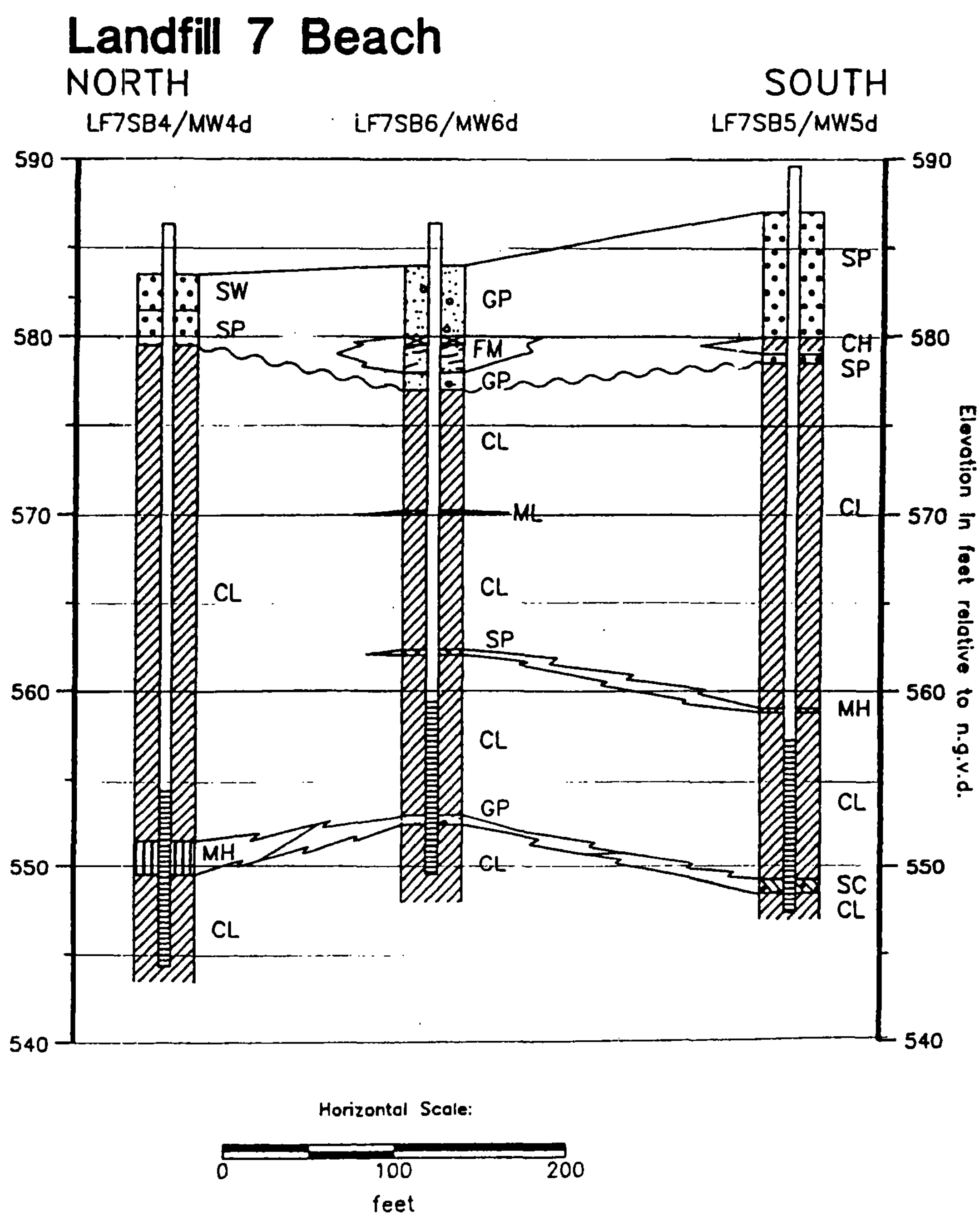


Figure 8: Landfill 7 Slope Profiles - 1980 Design Plans



3. ALTERNATIVES

After the 1994 investigation report was completed, the Army initiated an effort to consider several alternatives for rectifying the situation and devising a permanent solution to the problems regarding Landfills 6 & 7. According to the Army, the most important criteria considered were the overall protection of the environment and adhering to regulations regarding landfill closure. Some other considerations were permanence, leachate and gas treatment effectiveness, short-term effectiveness, implementability and cost. After considering many alternatives at the outset, the Army narrowed their focus to three main alternatives, which are discussed below. The alternatives were established based on the available knowledge concerning the contents of the landfills as was apparent from limited sampling and historic records.

3.1 Capping with RCRA Cap

The primary element of this solution is a more rigorously engineered cap than what was placed in 1982. It is designed to be a more effective version of what was done as part of the 1982 closure. This option has the following features:

1. Construction of a new perimeter storm drain to replace the existing drain
2. Leachate would be collected in the storm drain running underneath the Landfills
3. Leachate from this drain and the interception trench would be treated
4. A RCRA cap would be placed on the landfill
5. Waste in outlying areas of landfill would be consolidated
6. Gas emissions will be actively collected and treated by burning

A more extensive description of this option is included in the Interim Action section (Section 4.)

3.2 Capping with a Modified RCRA Cap

This option is similar to the RCRA equivalent cap option in most respects except for the type of cap to be installed. The primary difference is that a layer of compacted clay in the RCRA cap is replaced with a layer of Geosynthetic Clay. This design is expected to be more impermeable to water than compacted clay and more stable on a steep grade. This design also has an increased buffer of fill between the cap and landfill due to the greater risk of a puncture cause failure from materials in the landfill.

3.3 Excavation

This is the plan that would be the most beneficial over the long term, but it would pose short term challenges and would be more expensive than capping. Essentially, this plan involves removing the contents of the landfill, disposing of it off site and returning the ravine to its natural state. This plan has the following elements:

1. Leachate extraction and treatment
2. Storm water controls
3. Excavation of the landfill with the contents trucked off site
4. Disposal of the waste in a sanitary landfill, a hazardous waste landfill, or an incinerator, depending on its contents
5. Air emission/Landfill gas controls
6. Site restoration

The first step would be similar to the leachate collection under the capping alternative, but it would be for the short term only. The waste must be dewatered before it can be excavated. In the excavation alternative, the passive gas venting wells from the 1982 closure would be converted into leachate recovery wells. Leachate could be drawn out of these wells until the landfill was effectively dewatered. This leachate would have to be trucked off site and treated.

Storm water controls would be important because there is a significant likelihood of a discharge from the excavation area.

When disposing of the material, it must be classified to determine its degree of hazard and the accompanying regulations. If the excavated material is deemed to not be hazardous, it may be disposed of in an ordinary offsite landfill. If the waste were deemed to be hazardous, it could be disposed of in a hazardous waste landfill. If the waste is determined to be subject to land disposal restrictions, it would need to be incinerated. The current classification of the waste based on the history of materials placed in there is hazardous, which may be changed based on further testing.

The excavation process for the waste is quite simple. Regular backhoes can be used. The waste would then be placed in trucks to be carried to the appropriate disposal venue. During this process, care would be taken to limit the emission of odor and toxic gasses from the landfill. This could be done through the application of chemicals to the refuse.

3.4 Comparative Analysis

According to the consulting firm' s reasoning, all three alternatives provide an adequate level of environmental protection with the excavation providing better long term benefits but with more short term risks. The firm points out that the excavation option would be much more time consuming and expensive. They estimate an excavation project would take 3.5 years to complete from the first truckload to the last. Tables showing the estimated costs of all design options are included in Tables 1-5.

After being presented with the information summarized above, the Army choose to combine the two capping alternatives. They decided to place a RCRA equivalent cap on the bulk of the landfill and place a modified RCRA cap on the East Face. The primary reason for this is the enormous cost involved with excavation. As demonstrated in Table 5, this cost could exceed $700 million, instead of about $17 million for the capping alternatives if the waste was discovered to be so hazardous that all of it would need to be treated prior to landfilling. Apparently, the Army also believes that the transient difficulties posed by excavation are a formidable barrier to excavation. The Army elected to use a modified RCRA cap on the East Face because it is easier to install and is more durable on the sloping environment. It also is less permeable, which is important due to the serious erosion issues on the East Face. Further description of the selected plan is provided in the following section.

Table 1. Cost Estimate for Alternative 2 -RCRA Cap

Item	Cost
Initial Construction:	
Storm Drain System	$950,000
Interim Cover	$454,000
Leachate Collection System	$300,000
Leachate Treatment and Discharge System	$567,000
Landfill Gas Collection and Treatment System	$212,000
Shoreline Protection	$100,000
Waste Excavation	$50,000
Total Initial Construction cost	$2,633,000
Present Worth - Final modified RCRA Cover Construction	$3,764,000
Present Worth - Total Construction Costs	$6,397,000
Present Worth - Resident Relocation Cost for 5 years	$2,265,000
Present Worth - Annual Operation and Maintenance (Years 1-4)	$3,970,000
Present Worth - Annual Operation and Maintenance (Years 5-30)	$4,180,000
Present Worth - Equipment Replacement (Year 16)	$50,000
Total Costs	$16,862,000

Note: Assumes leachate is not hazardous waste

Assumes discount rate of 7 percent

Source: ESE

Table 2. Cost Estimate for Alternative 3 - Modified RCRA Cap

Item	Cost
Initial Construction:	
Storm Drain System	$950,000
Interim Cover	$454,000
Leachate Collection System	$300,000
Leachate Treatment and Discharge System	$567,000
Landfill Gas Collection and Treatment System	$212,000
Shoreline Protection	$100,000
Waste Excavation	$50,000
Total Initial Construction cost	$2,633,000
Present Worth - Final modified RCRA Cover Construction	$4,081,000
Present Worth - Total Construction Costs	$6,714,000
Present Worth - Resident Relocation Cost for 5 years	$2,265,000
Present Worth - Annual Operation and Maintenance (Years 1-4)	$3,970,000
Present Worth - Annual Operation and Maintenance (Years 5-30)	$4,180,000
Present Worth - Equipment Replacement (Year 16)	$50,000
Total Costs	$17,179,000

Note: Assumes leachate is not hazardous waste

Assumes discount rate of 7 percent

Source: ESE

Table 3. Cost Estimate for Alternative 4 - Excavation (100% Special Waste)

Item	Cost
Waste Sampling Program	$170,000
Temporary Storm Drain Improvements	$100,000
Temporary Cover Improvements	$100,000
Leachate Collection System	$350,000
Leachate Treatment and Discharge System	$468,000
Excavation - Hazardous Waste	-
Excavation - Special Waste	$2,250,000
Transport - Hazardous Waste	-
Transport - Special Waste	$7,425,000
Disposal Fee - Hazardous Waste	-
Disposal Fee - Special Waste	$12,375,000
Treatment (Incineration)	-
Air Monitoring	$300,000
Odor Control	$450,000
Site Restoration	$315,000
Resident Relocation for 5 years	$9,959,000
Leachate Treatment and Disposal Operation and Maintenance	$3,453,000
Total Costs	$37,745,000

Note: All the costs are assumed to be initial construction costs

Source: ESE

Table 4. Cost Estimate for Alternative 4 - Excavation (100% of Waste in Hazardous Waste Landfill)

Item	Cost
Waste Sampling Program	$200,000
Temporary Storm Drain Improvements	$100,000
Temporary Cover Improvements	$100,000
Leachate Collection System	$350,000
Leachate Treatment and Discharge System	$468,000
Excavation - Hazardous Waste	$4,500,000
Excavation - Special Waste	-
Transport - Hazardous Waste	$6,435,000
Transport - Special Waste	-
Disposal Fee - Hazardous Waste	$108,900,000
Disposal Fee - Special Waste	-
Treatment (Incineration)	-
Air Monitoring	$300,000
Odor Control	$450,000
Site Restoration	$315,000
Resident Relocation for 5 years	$9,959,000
Leachate Treatment and Disposal Operation and Maintenance	$3,453,000
Total Costs	$135,500,000

Note: All the costs are assumed to be initial construction costs

Source: ESE

Table 5. Cost Estimate for Alternative 4 - Excavation (100% of Waste Treated)

Item	Cost
Waste Sampling Program	$200,000
Temporary Storm Drain Improvements	$100,000
Temporary Cover Improvements	$100,000
Leachate Collection System	$350,000
Leachate Treatment and Discharge System	$468,000
Excavation - Hazardous Waste	$4,500,000
Excavation - Special Waste	-
Transport - Hazardous Waste	$6,435,000
Transport - Special Waste	-
Disposal Fee - Hazardous Waste	$9,900,000
Disposal Fee - Special Waste	-
Treatment (Incineration)	$675,000,000
Air Monitoring	$300,000
Odor Control	$450,000
Site Restoration	$315,000
Resident Relocation for 5 years	$9,959,000
Leachate Treatment and Disposal Operation and Maintenance	$3,453,000
Total Costs	$711,530,000

Note: All the costs are assumed to be initial construction costs

Source: ESE

4. INTERIM ACTION & EVALUATION

4.1 Description of the design elements

This section presents the details of the key design elements for the Landfills 6 and 7 interim remedial action. An overview of the selected plan is presented in Figure 9. Figure 10 shows an illustrative plan and perspective of the areas where the landfills are located after the interim action would be fully implemented.

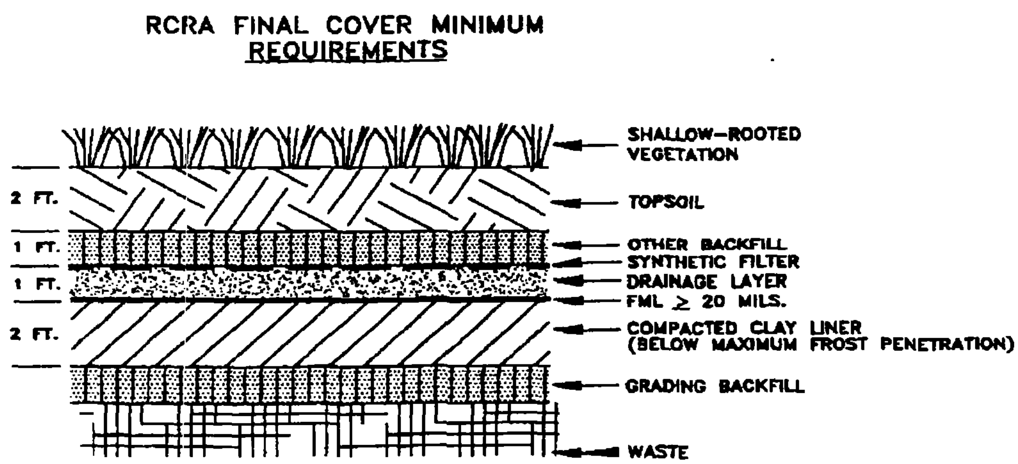
4.1.1 RCRA/RCRA-modified landfill caps

The cap was chosen as part of the interim action first and foremost, according to the Focused Feasibility Study, to protect the neighboring communities and the environment from the unacceptable risk due to release of hazardous substances. The FFS states that the landfill covered with a non-engineered layer of topsoil suffered from multiple problems including leachate build-up, cap fissures, landfill gas emissions, and leachate seeps. The new engineered cap as incorporated into the interim action was to do the following:

a) provide containment for the buried waste
b) preclude future users of the landfills from potentially coming into direct contact with the waste
c) prevent surface infiltration of storm water into the landfills
d) minimize/preclude the emission of landfill gas through the surface of the cap

Figure # 11 shows a cross section of the cap which was installed as part of the interim action.

Figure 11: RCRA cap on Landfills 6 & 7



The cap components illustrated in the figure above are as follows:

- A composite geonet layer (which acts as the gas migration/leachate drainage layer)
- A GCL
- A 40-mil LLDPE textured geomembrane (textured to provide an additional factor of safety)
- A composite geonet layer (which acts as a drainage layer for surface water that infiltrates through the vegetative topsoil/protective soil layers)
- A protective soil layer (that will have a minimum thickness of 3 feet)

Figure 9: Landfills 6 & 7 Site Plan - Closure in Place Alternatives

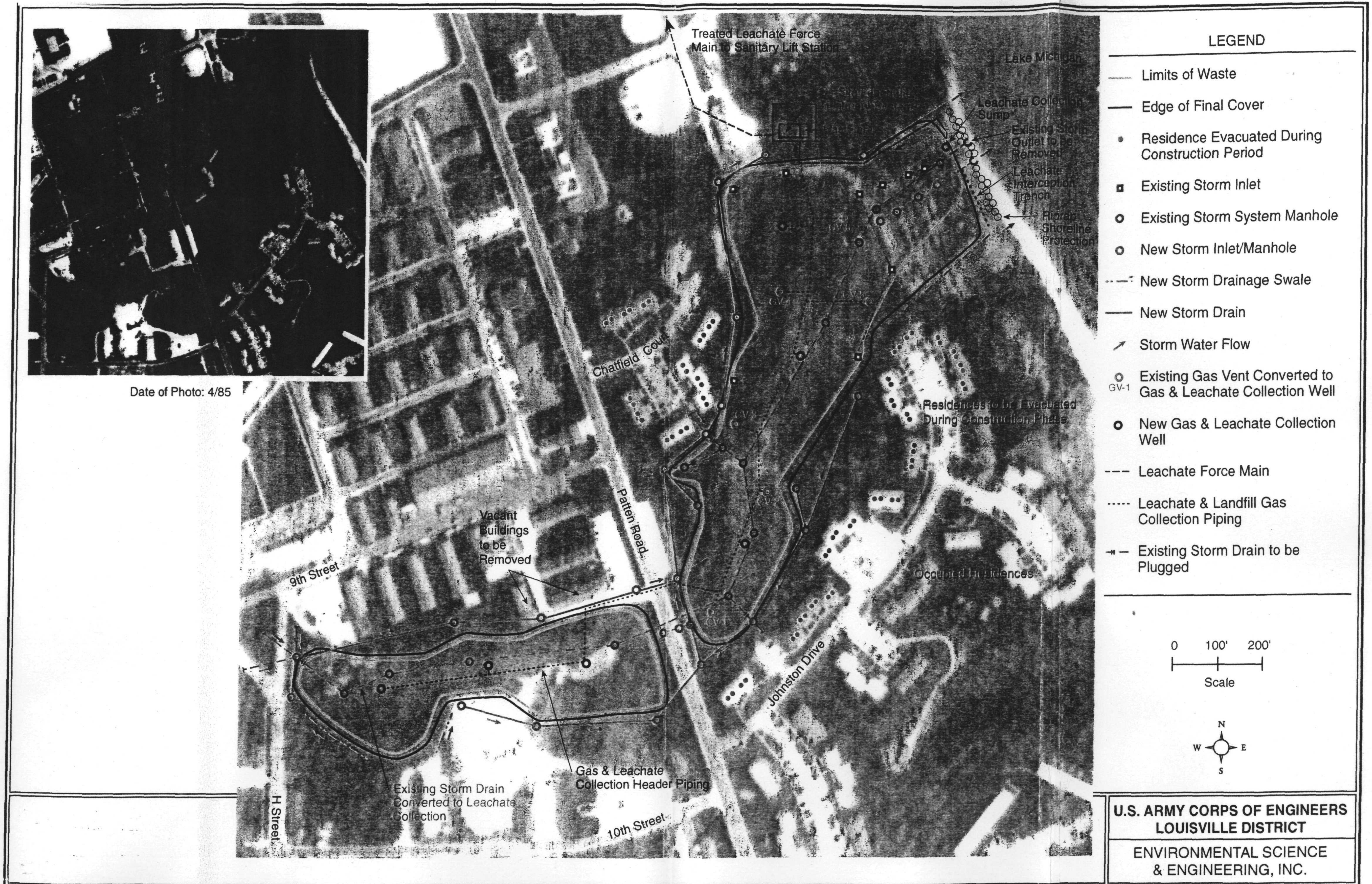
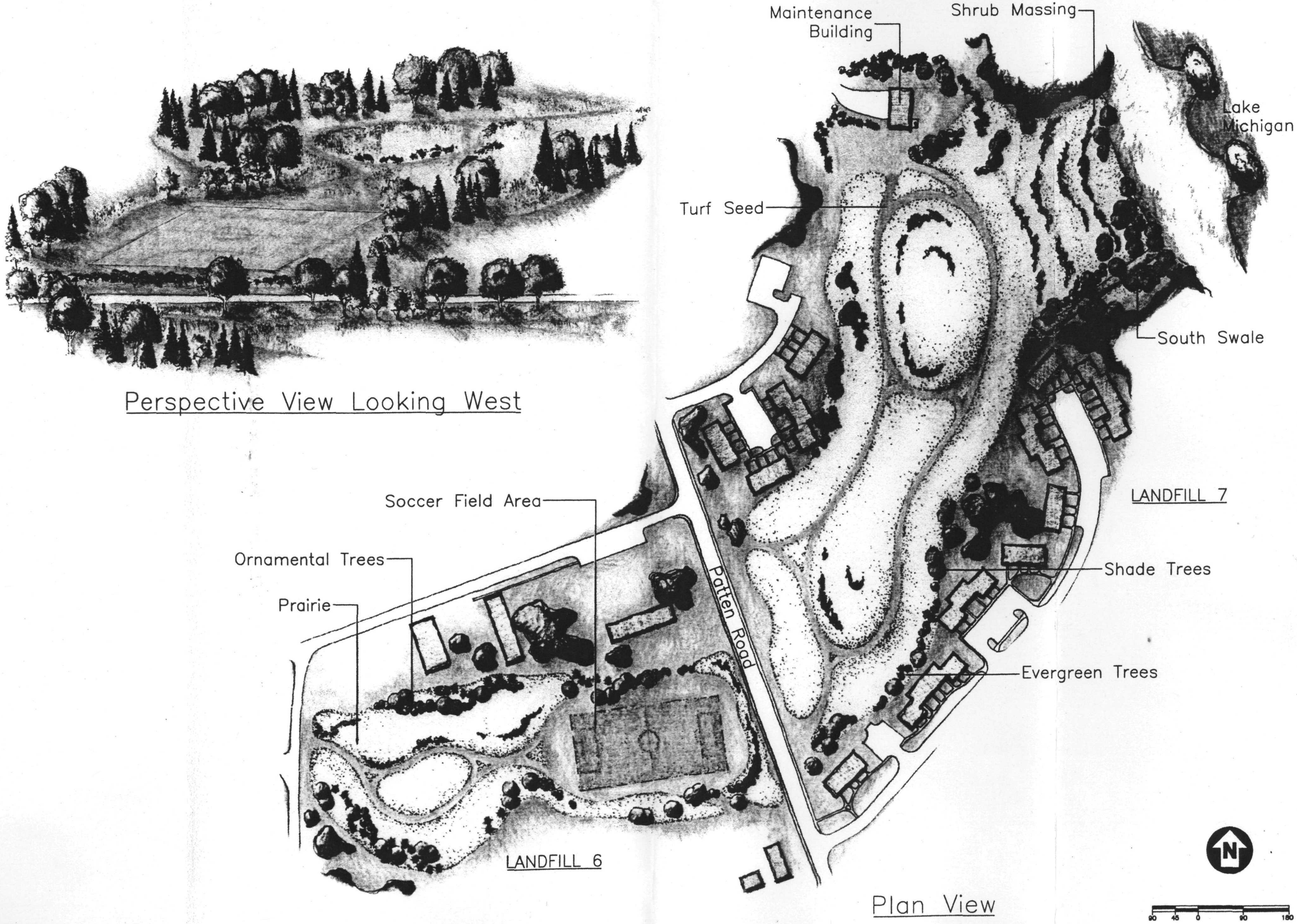


Figure 10: Illustrative Plan and Perspective



- A vegetative soil top layer (that will have a minimum thickness of 0.5 feet)

The combined thickness of the protective soil layer and the vegetative topsoil layer will ensure that all of the geosynthetic components of the cap will be located below a 42-inch frost penetration depth.

The cap was designed to prevent storm water from penetrating the geosynthetic components of the cap and allowing it to drain into the Perimeter Cap Drain system, which consists of storm drain inlets, spaced around the perimeter of both Landfills 6 & 7.

A modified RCRA-Cap was constructed on the Landfill 7 East Slope to provide for increased stability and erosion protection. The design of this cap was to do the following:

a) facilitate the construction of a stable cap system that will provide containment of the buried waste
b) preclude future users of the Landfill 7 East Slope from potentially coming into direct contact with the waste
c) minimize the volume of waste material that will have to be excavated from the East Slope to facilitate construction of a stable cap system along this face
d) facilitate the collection/management of leachate seeps
e) provide for efficient and effective removal of storm water that contacts and/or infiltrates through the topsoil and protective cover soil layers along the East Slope
f) prevent surface infiltration of storm water into the landfill waste present along the East Slope

Figure 12 shows the cross section of this modified RCRA-Cap.

The design of the cap for both Landfills 6 & 7 incorporates several different features and systems which provide for the drainage of surface water into the Perimeter Storm Drain, and thereafter, into Lake Michigan via the existing Storm Water Outfall Structure.

Although the Interim Action report addresses the problems of erosion due to surface water drainage in detail by incorporating properly sized swales, benches, and erosion control blankets, the issue of shoreline erosion, which may cause serious bluff instability and cap failure as will be demonstrated later in this report, is completely avoided by the authors.

Figure 12: Modified RCRA-cap on Landfill 7 East Slope

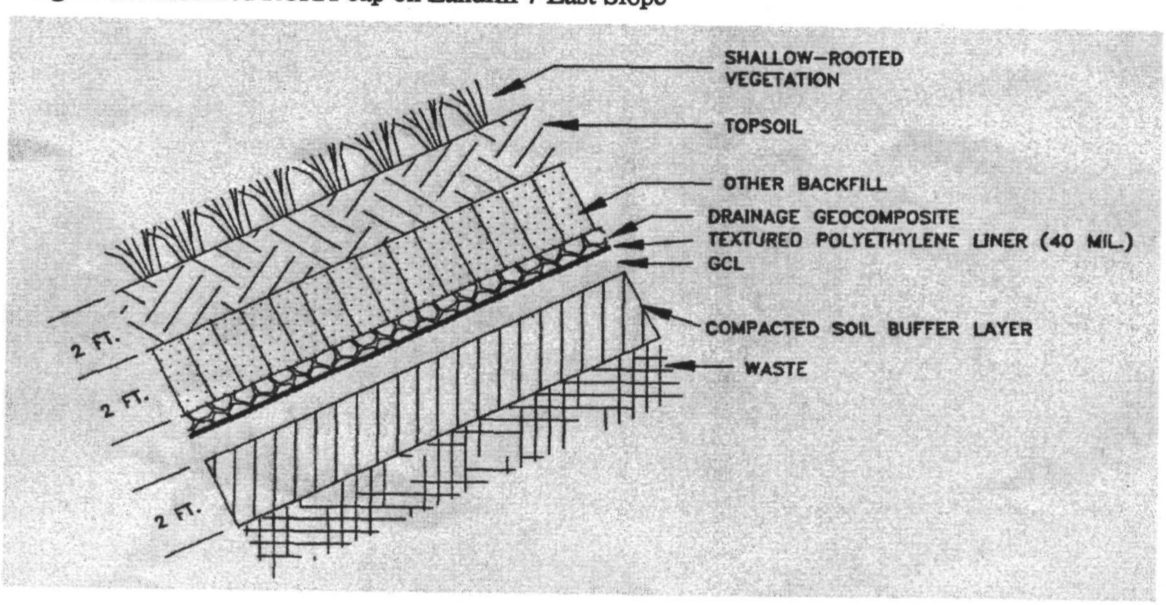


Figure 13: Landfills 6 & 7 Groundwater Elevations (April 1995)

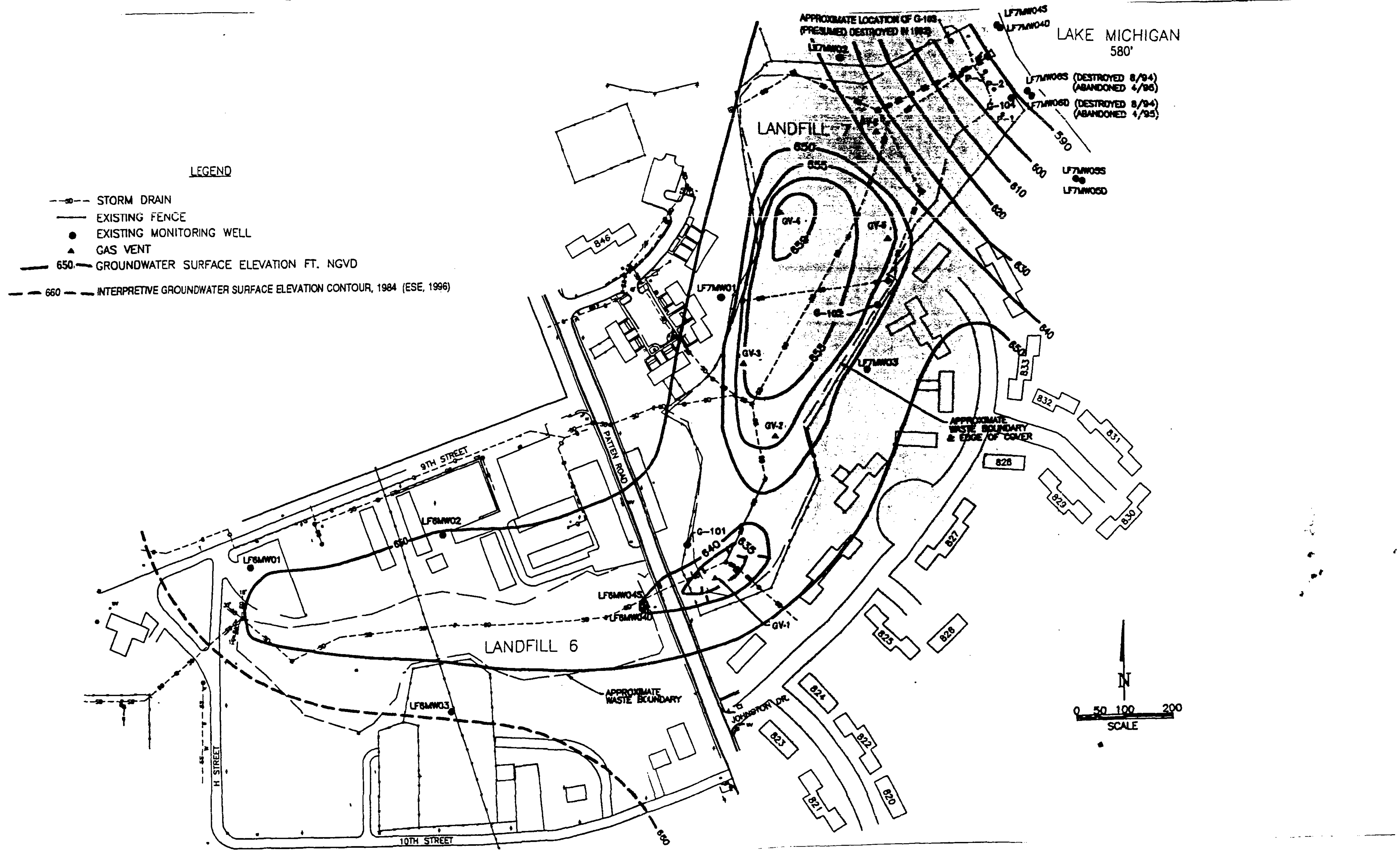
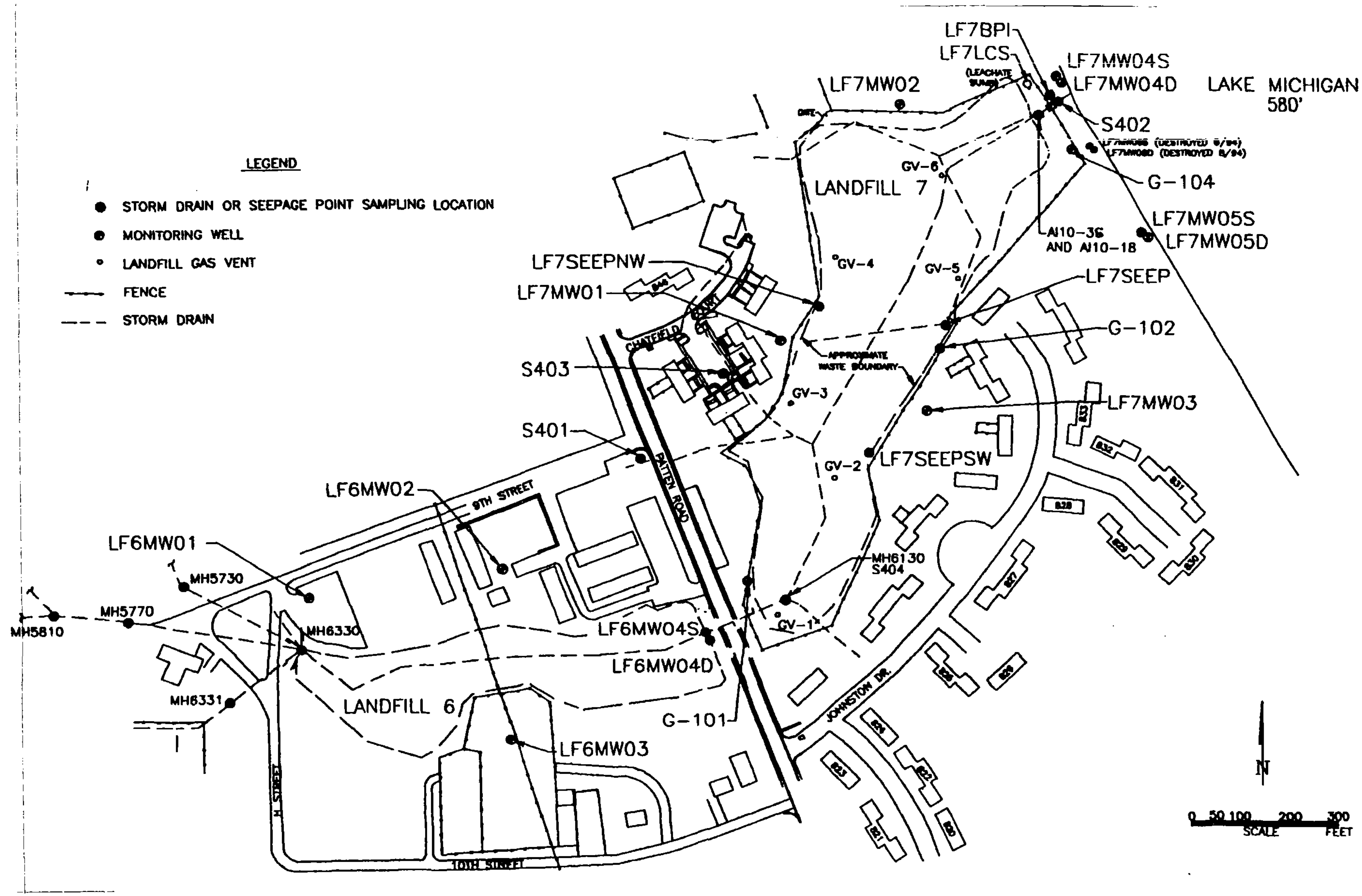


Figure 14: Landfills 6 & 7 Water and Leachate Sampling Locations



4.1.2 Leachate Collection System

The leachate collection system as incorporated into the Interim Action will include collection of leachate via a) the Leachate Collection Drain that runs along the bottom of Landfills 6 & 7, and b) the Leachate Interception Trench, which lies along the base of the Landfill 7 East Slope, preventing the collected leachate from migrating into Lake Michigan. The system also involves automated pumping of the collected leachate into storage tanks, located in the maintenance building situated just north of Landfill 7, which will be periodically emptied by tanker trucks and sent to an off-site treatment and disposal facility. The goal of this leachate collection system, as described in the Interim Action report, in conjunction with the cap on Landfills 6 & 7 will help lower the leachate levels thus causing an inward gradient of groundwater and preventing any leachate/impacted groundwater from migrating off-site. As can be seen from Figure 13, the groundwater gradient is currently outward, thus creating the possibility of contaminated groundwater traveling outside the boundaries of the waste. The current locations of leachate and groundwater sampling points are shown in Figure 14.

The report acknowledges the fact that capping the landfills and increasing the pumping of leachate may cause the collected leachate to have properties different from the leachate currently disposed of off-site. However, it doesn' t expand on this issue of how it might change, but rather assumes that the leachate may continue to be sent to the facility at which it is currently being disposed.

4.1.3 Landfill gas collection and flaring system

The gas collection system implemented as part of the Interim Action was designed to prevent landfill gas from migrating off the landfills, emitting onto the surface of the landfills, or building up within the landfills. The gas extraction system with a continuous final cover system over the waste consists of the following components:

- A composite geonet gas migration layer
- Deep gas collection wells that will facilitate the creation of a vacuum influence over the entire volume of both landfills, below a depth of 5 feet
- A network of perforated shallow lateral gas collection pipes that will create a vacuum influence in the top 5 feet of the landfills
- A gas blower and enclosed flare system that will collect and treat (burn) the landfill gas prior to discharge to the atmosphere
- Associated gas condensate traps
- A supplemental natural gas source to facilitate landfill gas combustion

The goal of this gas collection is to achieve a vacuum within the landfill of no lower than 15 inches of water after incorporating a safety factor to account for the heterogeneity of the landfills. However, when performing sensitivity analysis, the authors of the report site a value for the hydraulic conductivity of the waste which is an order of magnitude higher compared to the results obtained from testing during the Focused Feasibility Study (FFS.) The average hydraulic conductivity of the waste was determined to be approximately 2 x 10^{-4} cm/sec, while in the Interim Action report a value of 1.6 x 10^{-3} cm/sec is given. Thus when performing the sensitivity analysis the authors should have obtained a low-end permeability on the order of 5 x 10^{-6} not 10^{-5} cm/sec. Even though the assumption that this lower permeability waste material would probably not occur everywhere within the landfills is not unreasonable, the assertions made in the report about the ability of the blower system to create a vacuum throughout the three-dimensional volume of the landfills are not entirely convincing due to the inconsistency in permeability values. Additionally, the schedule for operation of the blower system seems highly variable and unclearly defined in the report. The authors propose two courses of action in the event that the flow from the landfills drops below the specified 53 scfm, without providing guidelines for choosing between the two alternatives or the exact specifications with respect to the latter (e.g. the explosive limits of methane, the amount of air which may be introduced, the time duration of the blower shut-down.)

4.2 Evaluation of Interim Action and Focused Feasibility Study (FFS)

A large amount of information, data, and estimations obtained from the FFS as well as other studies performed by various consultants were incorporated into the Interim Action assuming that information/data contained in these documents are accurate. The following section of the report evaluates the flaws, deficiencies, and inconsistencies found in the Interim Action and the FFS.

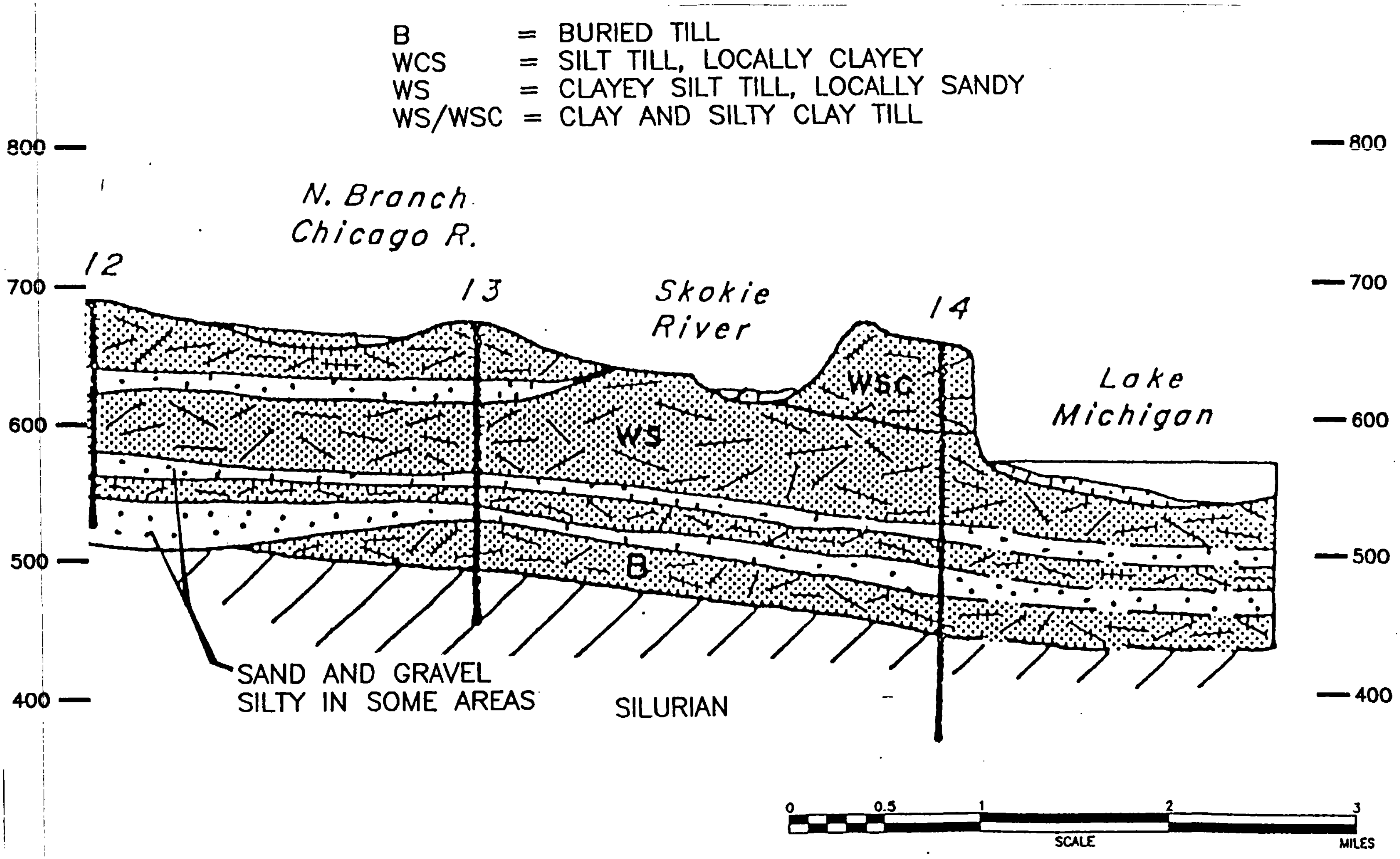
The Army's choice to cap the landfills appears to be biased in favor of the selected alternative. The FFS, which was written in 1996 prior to the installation of the current storm water management system was already calling Alternative 2, the expected final remedy. The cost of the interim remedy was so significant, that the investment of such large sums of money into its implementation leads to the conclusion that the ultimate remedy has already been predetermined. Less expensive options would have sufficed to deal temporarily with the problems of gas emissions, that according to the Army, posed an environmental and health threat to the surrounding communities, while a more permanent solution was being established.

In response to the comments, concerns, and questions brought up during the public comment period the Army was often vague in its answers. Particularly interesting was the use of the phrase "relatively well defined" with respect to many parameters such as leachate levels, hydraulic conductivity, health risk, and contents of the landfills. The above mentioned issues deserve more attention and require less uncertainty when dealing with an unlined landfill located so close to residential communities and a major drinking water source.

The Army also did not address the failure of the previous cap. As mentioned previously, the 1982 cap, although less engineered, failed to satisfy its purpose for many reasons including ineffective gas collection, ponding, slope instability, and leachate seepage. No landfill cap will last forever, and past experience suggests a high likelihood of cap failure and the necessity for replacement within the next 30 years. However, the Army chooses to rely on the laboratory testing data of the cap materials rather than past incidences to make their cost estimates of the capping alternative.

Additionally, testing has suggested that within the supposedly impermeable clay there are seems of sand, silt, and gravel that are much more conductive then the impervious clay till material present, which largely makes up the bluff geology. An East-West geologic cross section near Fort Sheridan is depicted in Figure 15. Some groundwater sample analyses also suggest the contamination of groundwater with leachate. Specifically monitoring well pair LF6MW04S and LF6MW04D installed between the landfills show responses indicative of leachate migration through the soils between the landfills based on the difference in the chloride/sulfate balance between the two wells. Another reason for concern is the determination of hydraulic conductivity from slug tests using the Bouwer and Rice method which was noted by Charles Norris of Geo-Hydro, Inc. to be inappropriate for at least one and possibly two wells (LF7MW04S and LF6MW04D.) The slug test data should generate a semi-log plot of residual head (log) vs time (linear) that is a straight line. Howerver, the data do not generate this straight line. Rather, they form curvilinear patterns with a continuously decreasing slope with time. The leachate and groundwater sampling locations can be found in Figure 14. Therefore, the hydraulic

Figure 15: Landfills 6 & 7 East-West Geologic Cross Section – Near Fort Sheridan



conductivity determined for the soil under and surrounding the waste may not be correct. This issue requires further investigation to determine the actual conductivity of the bluff.

An issue of tremendous concern is that the Army did not fully characterize the waste prior to the cap installation. Numerous comments were brought up with respect to this critical issue. If the cost of excavation, and the treatability of the leachate and gas are impacted so much by the nature of the landfills' contents then more effort should have been applied towards identifying the major components of the waste. Despite the volume of requests to perform testing of the waste rather than leachate and collected gas, the Army continues to maintain that the waste is "relatively well" characterized and sufficient information is available to make a final decision. The following excerpt is taken from a 1989 Enhanced Preliminary Assessment Report prepared by Argonne National Laboratore for the U.S. Army Toxic and Hazardous Materials Agency:

"The wastes that were disposed of into the Wells Ravine landfill... were highly varied and essentially consisted of any and all wastes that were generated on-site. At one time, prior to 1970, it was common practice for a dump truck or other vehicle carrying a 'lugger bucket' to make rounds on Fridays and collect any and all wastes that the various shops needed to dispose of; this collection was taken to the landfill and dumped. A partial list of the different types of waste that were disposed of includes waste oil, solvents, paint, paint thinner, paint stripper, carbon cleaning compounds, hospital and veterinary wastes (including out-of-date chemicals and medicines of all types), photographic chemicals, ammunition boxes that had been treated with pentachlorophenol, radioactive dials and gauges, sewage treatment plant sludge, incinerator and heating plant ash, building debris (including asbestos shingle, siding, and insulation), and domestic and office refuse."

Additionally the Army claims that sufficient information is available to classify Landfills 6 & 7 as Municipal Solid Waste (MSW.) However, according to United Nations Environment Programme (UNEP), "about 10% of the approximately 1,200 sites on the US "Superfund" list of hazardous waste sites are former MSW landfills." So how can it be acceptable to let this "relatively well characterized" waste remain buried and undisturbed next to residential communities, under the feet of children, and so close to a major source of drinking water with two water intakes located within 10 miles of the Landfills.
3

Another issue of concern is the fact that the 10gpm (gallons per minute) figure cited by the Army in the FFS to be the average leachate flow through what used to be the storm water drain along the bottom of the ravine, and has now become the Leachate Interception Drain, appears to be overly high for the amount of average precipitation that could drain through the landfill into the storm water drain. It's also clear from the data provided in the FFS that the composition of the 10gpm is highly inconsistent with the composition of any of the leachate compositions, but that it was fully consistent with the composition of the water from storm drains upgradient to the landfills. Thus it appears that what the Army was interpreting as leachate sample analysis data was not actually leachate.

The vinyl chloride detected in gas prior to the capping of the landfills was used as a basis for immediate capping of to protect the neighboring communities from the potential risks associated with landfill gas emissions. Yet no precursors of vinyl chloride such as chlorinated solvents or possible DNAPLs (dense non-aqueous phase liquid) have been identified. The Army acknowledges the fact that the design of the leachate collection system may not intercept and collect the DNAPL present. The Army also neglects the fact that the presence of DNAPLs would affect the treatability of the landfill leachates and landfill gases because simple flaring will not destroy some chlorinated compounds. Thus, additional costs may be incurred.

4.3 Shoreline Erosion

Although the FFS address the question of erosion, specifically in response to the public comments, there are no quantitave arguments presented by the Army to demonstrate that erosion will not cause failure of the landfill and the catastrophic exposure of the waste to Lake Michigan waters.

This section of our report focuses on a 1994 U.S. Geological Survey (USGS) study entitled "Rates and Processes of Bluff Recession Along the Lake Michigan Shoreline in Illinois." The full text of this paper can be found in Appendix II. This study demonstrates that erosion along the bluff region from Wilmette to Waukegan is a naturally occurring process independent of lake levels, precipitation, bluff height, bluff lithology, and shore-protective works. The report acknowledges the fact that erosion is not independent of these factors, but states that over a longer period of time such as the design life of Landfills 6 & 7, variances in these factors do not have a significant effect on retreat rates.

The study divided the 30-km strip of bluffs along Lake Michigan shoreline from Wilmette to Waukegan, Illinois into 100 meter segments and examined each segment with respect to bluff retreat rates for two time periods, 1872-1937 and 1937-1987.

From the results of the study it can be concluded that Landfills 6 & 7 are located within the Highland Park Moraine, classified as high bluff, which primarily consists of silty clay till that's more cohesive compared to silt, sand, or gravel, but more susceptible to large-scale episodes of landslides. The study notes that virtually the entire length of the high bluff shows evidence of historical activity with respect to erosion. "The thick vegetative cover provides a deceptive aura of stability, but most trees appear to be no older than 20-30 years, and few, if any, are older than about 50 years." This completely disarms the Army's argument that "there is no reason to expect that the eastern slope of Landfill 7 will slide into Lake Michigan (because it) has remained in place for 15 years in stable condition."

this was near [illegible] It could also represent when shore protection structures became commonplace.

The average rate of recession was found to be 22.6 cm/yr during the period of 1937-1987, which was over twice the rate found for the 1872-1937 period. The study further demonstrates that factors commonly considered to influence erosion rates have not been clearly shown to have an affect over time periods of several decades. These factors include lake levels, precipitation levels, bluff height, bluff lithology, shore-protective works, such as groins which have been largely installed along the Chicagoland waterfront since the 1920's. These shore-protective works may have created a more uniform spatial distribution of bluff retreat rates in the later part of the studies period but "these engineered works had little, if any, effect on the overall regional rate of bluff retreat." This is shown by the fact that the retreat has been parallel along the whole length of the studied shoreline.

Another 1999 report produced by the U.S. Army Corps of Engineers in conjunction with the Great Lakes Commission also warns the public about the dangers of relying on structural options for erosion protection. It discusses a number of engineered structures such as reventments, bulkheads, breakwaters, and groins but concludes that "none of these options, are permanent solutions against the continued and relentless forces of nature." The conclusion stresses the importance of relocation of near shore structures that are vulnerable to damage from strom-induced flooding and erosion.

The Army demonstrated knowledge of the USGS report, but chose to take one phrase out of this involved study and use it to justify the Interim Action. The following quote was taken directly from the published document:

"The data and conclusions from this study are relevant for regional planning rather than for site-specific engineering."

However, the army neglected to include the next sentence which reads that any "construction near the bluffs must anticipate some amount of bluff recession and stipulate sufficient setback to insure the integrity of structure for its anticipated life." It's reasonable to assume that if Landfills 6 & 7 are left in place their life would extend beyond the 30 years required by the EPA. With the average recession rate of 22.6 cm/yr, the edge of the waste would need to be at least 11 meters away from the edge of the bluff to survive 50 years.

5. CONCLUSIONS AND RECOMMENDATIONS

After reviewing the information mentioned in this report the authors of this report have come to the conclusion that the Army has not applied sufficient efforts to determine an adequate solution to deal with the landfills. More specifically, the expected final remedy as implemented in the form of capping for the interim action doesn' t satisfy all the ARARs. The Army doesn' t effectively consider the issue of shoreline erosion either in the interim action plan or in the Focused Feasibility Study. Thus, there is not enough information to determine whether the contents of Landfill 7 ~~will~~ be adequately protected from contact with Lake Michigan waters for the design life of the landfill. Additionally, these contents are not properly characterized, and the design life of the landfills is not clearly defined nor immediately apparent due to the poor characterization of the waste. Also, evidence suggests that engineered caps similar to the one installed as part of the interim action fail before the minimum expected design life of 30 years.

Based on these findings, the authors of this report established the following recommendations for possible future actions the Army should undertake:

- Characterize the waste, especially the radioactive component which has not been analyzed to date, and primarily in the area closest to the toe of the bluff which is at more immediate danger from erosion
- Modify the cost of the capping alternative to include the probable replacement of the cap within the 30 year design life
- Consider more serious shoreline erosion controls such as sheet pile and include these costs into the cost for the capping alternative.
- Establish a scenario for a contingent excavation (i.e. a possible future situation when an excavation will become necessary and include it in the record of decision.

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APPENDICES

Appendix I. Summary of U.S. Army 1995 Gas Vent Sampling - Vinyl Chloride, Benzene, Carbon Tetrachloride, and Chloroform (µg/m3)

Location	Date	Vinyl Chloride µg/m^3	Benzene µg/m^4	Cerbon Tetrachloride	Chloroform
GV-1	07-Aug-95	<8	8.92	<8	<8
	08-Aug-95	<8	20.65	1.54	1.63
	10-Aug-95	<17	18.4	<17	<17
	11-Aug-95	<17	<17	<17	<17
GV-2	07-Aug-95	19.71	<8	1.75	<8
	08-Aug-95	8.32	<8	<8	<8
	08-Aug-95	36.9	13.8	<8	<8
	10-Aug-95	100	33.4	<17	<17
	11-Aug-95	<17	<17	<17	<17
GV-3	07-Aug-95	68.9	11.82	<8	1.05
	07-Aug-95	35	<8	<8	<8
	08-Aug-95	809	130	<8	6.12
	10-Aug-95	<17	<17	<17	<17
	10-Aug-95	24.8	<17	<17	<17
	10-Aug-95	58.9	23.4	<17	<17
	10-Aug-95	22.9	<17	<17	<17
	11-Aug-95	<17	<17	<17	<17
GV-4	07-Aug-95	<8	259	1.85	6.47
	08-Aug-95	8.56	469	<8	8.87
	10-Aug-95	<16	22.8	<16	<16
	11-Aug-95	<17	32	<17	<17
	11-Aug-95	<17	34.6	<17	<17
GV-5	07-Aug-95	<8	28.24	<8	2.24
	07-Aug-95	<8	15.09	<8	2.57
	08-Aug-95	<8	38.9	<8	5.26
	10-Aug-95	<15	29	<17	<17
	10-Aug-95	<15	<15	<15	<15
	11-Aug-95	<17	23.4	<17	<17
GV-6	07-Aug-95	531	286	<8	4.33
	08-Aug-95	483	322	<8	4.47
	08-Aug-95	458	647	<10	<10
	10-Aug-95	364	338	<17	<17
	11-Aug-95	42.9	101	<17	<17
	11-Aug-95	238	491	<17	<17

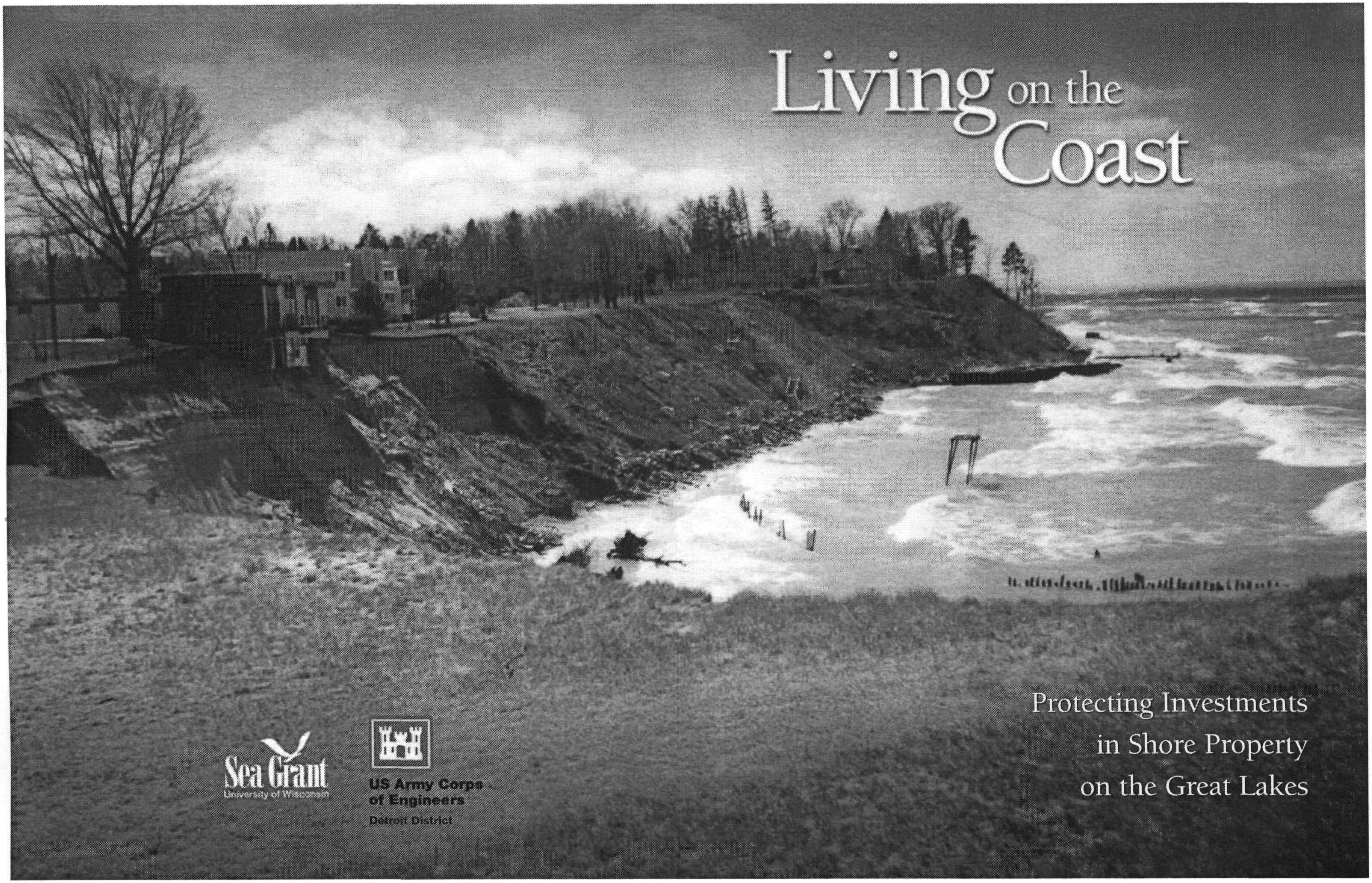
* Maximum sample holding time requirements were not met

Source: USACHPPM 1995

Appendix II: USGS Erosion Study

Exhibit A

Living on the Coast – Protecting in Shore Properties on the Great Lakes, U.S. Army Corps of Engineers and University of Wisconsin Sea Grant, (2003)


Living on the Coast
Protecting Investments
in Shore Property
on the Great Lakes
Sea Grant
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US Army Corps
of Engineers
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Information also contributed by the Wisconsin Association of Consulting Engineers

Note: CENG is a Chartered Engineer, the UK equivalent to a Professional Engineer (PE or PEng.) P.G. means Professional Geologist.

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INTRODUCTION

This booklet is about living and working on the attractive edges of the dynamic Great Lakes. There are risks from natural coastal hazards to be understood and managed when buying, building and operating private homes, residential and commercial developments, industrial buildings, and recreational facilities. This booklet provides information on the coastal environment and how to protect coastal investments.

A principal message

Do everything possible to avoid placing buildings and other structures where flooding, storm waves and erosion are likely to damage them or shorten their useful lives. If it is not possible to avoid these hazards, use shore protection methods that work with nature or have minimal negative effects on the nearshore environment and on neighboring properties.

This message is different from the message implicit in the *Help Yourself* booklet (1978) that this booklet replaces. The 1978 booklet promoted the use of traditional shore protection structures. This difference in message is due to an understanding that many traditional types of shore protection structures are undermined and their useful periods shortened by lakebed erosion and freeze/thaw cracking of armor stone. The difference is also due to a greater awareness of the adverse effects of many shore protection structures.

For whom is this booklet intended?

If you are interested in buying coastal property, this booklet will help you make an informed decision. The booklet will be a helpful resource if you are a realtor, banker, insurer, appraiser, regulator, developer, engineer, marine contractor or other professional person who influences coastal development. The scope of the booklet covers Canadian as well as United States shores of the Great Lakes.

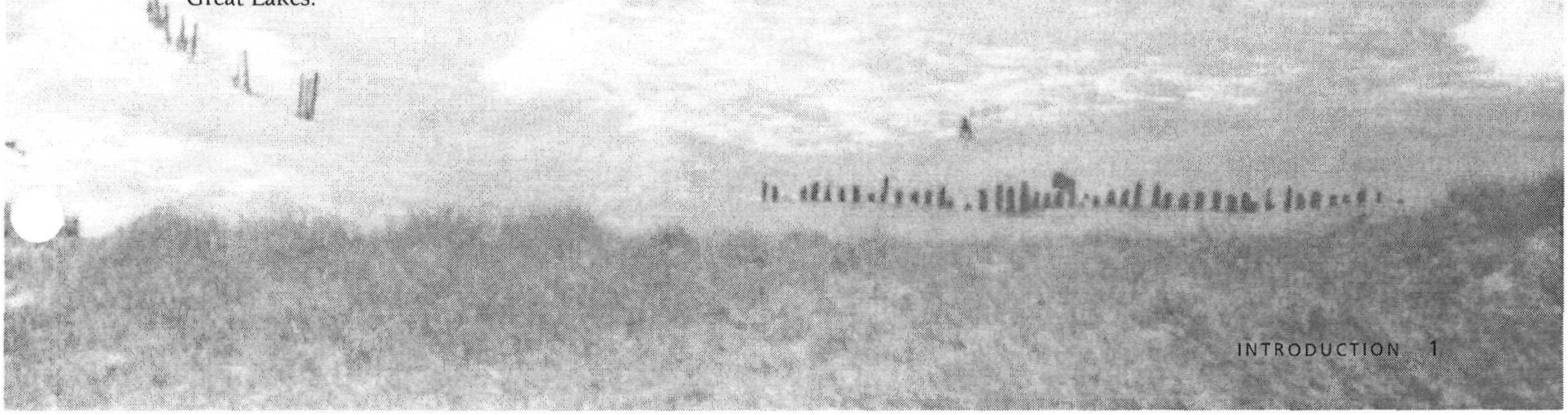
If you own coastal property on the Great Lakes, this booklet is also for you. For tens of thousands of present coastal property owners, the land remaining between building and lake is uncomfortably small and has been partly used up as erosion has carried away some of the land. The booklet contains information for people who are not able to relocate existing buildings to safe sites, people for whom improving stability of the land and shore protection seem to be the only option.

What's in the booklet?

Advice is offered on how to stabilize bluffs and banks, control surface water and groundwater, and build environmentally friendly shore protection structures. This work, in many situations, is no longer a "help yourself" proposition. Property owners should work together with neighbors to hire trained engineers and contractors to perform desired work.

The booklet begins with a brief description of the natural processes that affect the coast and those who live, work or play on the shore. The next section describes how to protect coastal investments and the environmental impacts of shore protection structures. The third major section is on risk management and the economics of protecting coastal investments.

This booklet complements the U.S. Army Corps of Engineers/Great Lakes Commission booklet *Living with the Lakes*, the University of Wisconsin Sea Grant Advisory Services publication *Coastal Processes Manual* and the Ontario Ministry of Natural Resources booklet *Understanding Natural Hazards*. More extensive information on the subjects covered in this booklet can be found in the U.S. Army Corps of Engineering *Coastal Engineering Manual* and in the Ontario Ministry of Natural Resources CD titled *Great Lakes — St. Lawrence River System and Large Inland Lakes Technical Guides for Flooding, Erosion and Dynamic Beaches.*



NATURAL PROCESSES THAT AFFECT THE COAST

The Legacy of the Glaciers

All of the Great Lakes except Lake Superior were river valleys about two million years ago when glaciers first entered the region. The Lake Superior basin was formed by faulting long before the glaciers. As many as 15 times, the glaciers formed and advanced from the north. Each time they came, they carved the lake basins deeper until they reached their present size beneath the last glaciation, which occurred between 25,000 and 10,000 years ago. Water levels in these basins fluctuated many dozens of feet (tens of meters) because of outlet changes, formation and removal of dams produced by glacial deposits (and by the glacier itself), climate variations, and tilting of the basins due to crustal rebound. Crustal rebound is the upward movement of the land that is still taking place because the land was pushed down by the weight of glacial ice more than a mile thick in places. Because ice was thicker in the north, the land was depressed more there; therefore the land is still rising more quickly in the north than in the south.

Glaciers erode rock and soil and carry it along with moving ice to the glacier edge where it is released from the melting ice and deposited as till, a mixture of sand, silt and clay. When the glaciers receded, there were many minor readvances of the ice edge. Each ice advance deposited till with a different composition. Between these till layers are layers or lenses of sand and gravel that were deposited in water in front of the retreating glacier. Between glacial advances there were also layers of silt and clay deposited on the lake bottom. These varied layers and lenses are now exposed in eroding bluffs and banks in many places along the shores. Water drains through the porous sandy/gravelly layers to the shore, creating slope instability.

All of the exposed soil materials in coastal slopes are subject to wave erosion, but different soil types have different properties. The varieties of soil types are particularly noticeable in high coastal bluffs. Some soils, like clay, can stand as very steep slopes when dry but may fail as large landslides when wet or severely undercut. Sand holds a more gentle slope and rarely fails catastrophically. In some places the shoreline consists of rock, with little or no sediment cover. This is especially true in the northern Great Lakes area where the glacier was mostly erosive, and the rock was resistant enough to withstand glacial erosion. There are also bedrock areas along many other Great Lakes shores.

The present shoreline position is not the shoreline position of the past. In bluff areas the shoreline may have retreated several miles since the last glacier melted away. Even bedrock shorelines have been eroded by waves, though to a lesser extent. Old shorelines are hidden in many places by modern shorelines. Low wave-cut terraces were portions of lakebed covered by sand during ancient higher water levels and lie in front of older shoreline bluffs. Former beaches and beach ridges are preserved inland above the present shore. Early footpaths and modern roads follow the old beach ridge crests. Along parts of the coast, sand supplies brought by coastal currents have pushed the present shoreline lakeward. Offshore, lakebed forms containing rooted stumps of bushes and trees are the remains of old shorelines and streambeds that existed when lake levels were much lower than at present.

Coastal property owners who plan to own the property for a long time are advised to anticipate future lake levels beyond the ranges indicated in the historical records.

Lake Level Responses to Weather and Climate

The midcontinental Great Lakes basin is subject to harsh, rapid changes in weather and climate. Each year, Great Lakes waters change from cold and ice covered to warm enough for swimming in as little as four months. The Great Lakes also can experience rapid changes in their water balance brought about by changes in the atmosphere. These changes may occur from season to season, over a few years, over ten years, or more. Lake levels are determined primarily by precipitation, evaporation, river and groundwater flows. (See the companion booklet, *Living with the Lakes*, for a description of the hydrologic cycle.)

Sometimes there are rapid lake level changes. On at least five occasions, Lakes Michigan and Huron rose or fell more than three feet (one meter) in about a year and a half. In about the same interval, Lake Erie rose nearly three feet in 1991-1993 and dropped about three feet in 1930-1931 and 1986-1988. In 1930-1931, Lake St. Clair dropped 3.8 feet (1.2 meters) in eight months.

Lake levels respond to the cumulative effects of weather systems passing over the Great Lakes basin. There are significant decade-to-decade shifts in the common tracks of storms that pass over or miss the lakes. Storm tracks are influenced by the high-altitude jet streams, and the jet streams are influenced by global atmospheric circulation patterns.

Periods of great shoreline damage and property loss are related more to times of high wave power than to times of peak water levels. The intensity and frequency of storm activity strongly influences lake levels and shoreline damage. Wave power is determined primarily by wind speed, wind duration, and the open water distance over which the wind is in contact with the water surface (fetch). Shoreline damage also depends on the erodibility of the shore and on water depths great enough for storm waves to reach these shores.

future climate and lake levels

Three methods are presently used to develop a range of plausible future climates and lake levels for the Great Lakes. They are based on the following:

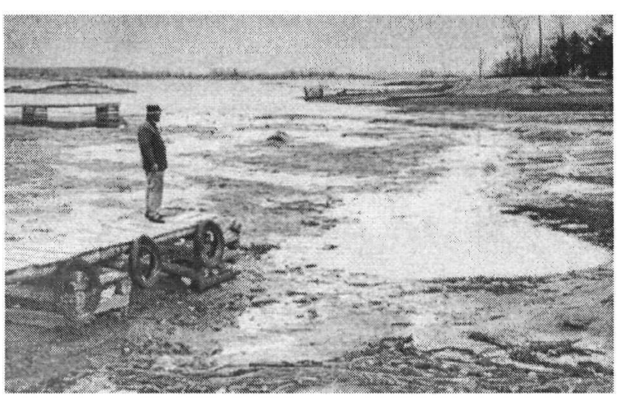
- climatic predictions from regional and global atmospheric circulation models (GCMs) for future climate changes, including global warming.
- transfer to the Great Lakes basin of real climatic conditions that occurred in other regions.
- statistical use of data from historical water supplies for computing possible extreme water levels and their probabilities of occurrence.

Plausible Future Climate Effects on Lake Levels

The Great Lakes have had their present connections for the past 3,000-4,000 years. Water level fluctuations over this time were due to natural climate variability, except for some effects from diversions and dredging of connecting channels since the 1850s. There has been a lot of experience in dealing with high levels over the last half of the 20th century but relatively little experience with low lakes levels. For information on past, present and expected future lake level ranges, see "Where to Go for More Information" at the back of this booklet.

The very short recorded history of Great Lakes water levels is inadequate to forecast lake levels that will occur in the next 20, 50 or 100 years. Future climatic conditions may be quite different.

Computer modelers ask, "What would happen to lake levels if climate conditions that developed elsewhere occurred in the Great Lakes basin?" The "borrowed" climate conditions may be extreme and short term (like the Mississippi River flood of 1993) or long term (such as Ohio River valley or gulf coast climates within the 20th century). These methods do not produce predictions or forecasts. They provide a range of plausible futures for exploring the implications of a changed climate system or future climatic variability that is not found in the climate records and lake level records of the Great Lakes basin. Technical judgment is needed to decide which scenarios of climate change seem most likely to occur.



Honey Harbour, Georgian Bay, 1964

Results from climate modeling are used with other models to estimate how lake levels will change in response to climate changes. The most important finding so far is that present high and low record levels could be significantly exceeded under some of the modeled scenarios.

If the extremely wet climatic conditions of the upper Mississippi River basin in the spring of 1993 had occurred in the Great Lakes basin instead, the Great Lakes would have experienced unusually rapid rises of one to two feet in three to four months, depending on the lake.

A major issue of importance is how the paths, intensities and frequencies of storms will change as the climate changes. Storm tracks shift in and out of the Great Lakes basin under the influence of the atmospheric jet streams. The jet streams are influenced by global atmospheric circulation patterns, which are controlled by sea surface temperatures in the oceans. Will global climate change bring regional climate changes that alter Great Lakes storms?

Human Influence on Lake Levels

Humans influence, but nature controls the water levels of the Great Lakes.

The *Living with the Lakes* booklet describes the system of diversions and control structures used to adjust outflows from Lake Superior and from Lake Ontario. Flow adjustments are made at two control points. On the St. Marys River at Sault Ste. Marie, river flow is mainly used by passing the water through power-generating turbines. Additional flow modifications are made by adjusting gates called the Compensating Works in a dam spanning the river. The flows are adjusted to balance desired lake levels upstream and downstream. On the St. Lawrence River at Cornwall, Ontario/Massena, New York, most of the river passes through power-generating turbines. Spillway gates in the Iroquois and Long Sault dams are used for ice control.

Flows at the two locations in both rivers are adjusted in a decision-making process that attempts to balance the various needs of Great Lakes users and shoreline property owners and to distribute the adverse effects of too-high or too-low water levels. This flow regulation process works well when natural climatic variations are slow and modest, and the seasonal cycles of lake levels are typical cycles with summer high levels and winter low levels. This flow regulation process does not work well when natural climatic variations are rapid, substantial and persistent. At such times, the lake level responses to flow adjustments are too slow and produce water level changes of a few inches when changes of a foot or more are desired.

Compared to no diversions, the combined effects of existing diversions of water into and out of the Great Lakes has resulted in raising Lake Superior one to four inches (three to nine centimeters). The effects on the other lakes were temporary and small: less than four inches (10 centimeters). Water flow control at Sault Ste. Marie since 1921 has had similar small effects on lake levels.

Dredging the connecting channels between the lakes has also had small but significant effects on water levels. Dredging in the St. Clair River since 1900 lowered the level of lakes Michigan and Huron by 11-16 inches (27-40 centimeters). This change affected both the mean water levels and the water level ranges of the natural seasonal cycle. Dredging of the river channels temporarily increased the level of Lake St. Clair a few inches (about six centimeters).

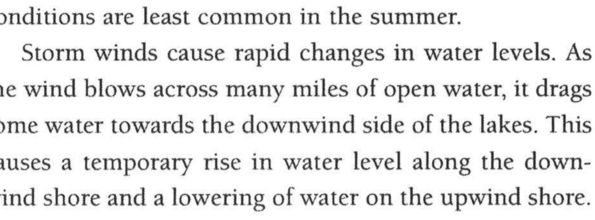
Storms and Storm Surges

As the wind blows across the surface of a Great Lake, energy is transferred from the wind to the water surface. Most of this energy generates currents. The rest of the wind energy builds waves. The lakes respond to strong winds more quickly with waves and storm surges than with currents. Storm winds may last less than an hour, or they may blow for three days or more. Storm wind conditions are least common in the summer.

A storm surge lasts about as long as the storm wind blows on shore; it rises rapidly with rising wind speed and drops as the wind speed falls or the wind changes direction.

Storm winds cause rapid changes in water levels. As the wind blows across many miles of open water, it drags some water towards the downwind side of the lakes. This causes a temporary rise in water level along the downwind shore and a lowering of water on the upwind shore. The temporary rise in water level is called a storm surge, storm set-up, or storm-induced rise. The drop in water level is a set-down. Storm surges and set-downs occur along all of the Great Lakes shorelines.

A storm surge may last all day. Storm surges in bays are typically larger than storm surges on the open coast. Storm surges on island and peninsular coasts are typically smaller than storm surges on the open coast. Storm surges typically rise one to two feet (0.3 – 0.6 meters) on the open coast, two to five feet (0.6 – 1.5 meters) in bays, and up to eight feet (2.4 meters) at the eastern end of



Lake Profile Showing Wind Set-Up

Lake Erie near Buffalo (with a similar set-down at the western end of the lake). For more on storm surges, see "Where to Go for More Information" on page 40.

Periodic oscillations of lake levels are called seiches. Seiches are caused by rapid changes in air pressure or rapid shifts in wind direction as weather systems pass over the lakes. Seiches last seconds to minutes and reoccur at intervals (or periods) of tens of minutes to more than eight hours. One or more seiches following a storm may cause repeated flooding of low-lying land.

An edge wave is a rare, sudden water level change caused by a fast-moving line squall crossing a Great Lake. These line squalls are called derechos. They typically move at 40 to 50 miles per hour (18–22 meters per second), with wind speeds within the storm fronts of 60 to 100 miles per hour (27–45 meters per second). Edge waves appear to originate near the location where the squall reaches the shore after crossing the lake. An edge wave races around the perimeter of the lake many miles from, and hours later than, the squall line passage. Edge waves are hazardous to people on breakwaters and may flood and damage lakeside buildings and marinas.

Trained design professionals take into account the various types of rapid water level changes that can occur at a particular site, when designing shoreline structures.

Temporary rises in lake level associated with storms need to be considered in order to minimize property damage from flooding and from larger waves reaching shore.

Waves and Wave Climate

The fetch distance (which is the length of water surface exposed to the wind), the wind speed, and the duration of the wind blowing from roughly the same direction over water are important factors in deep-water wave development. Deep-water waves have a range of heights and other characteristics at every location.

Storm wind speeds and storm wave heights can increase rapidly. A typical fall storm wind speed can increase from about 2 to 40 miles per hour (0.9-18 m/s) in less than eight hours. With such a wind speed increase, the lake surface may go from flat calm to rough with waves two feet (0.6 meters) high within an hour. Within eight hours, wave heights may approach 17 feet (5.2 meters), and higher. These deep-water waves move toward shore and form large breakers in the surf zone and in harbor entrances.

A wave climate record is the history of the distribution of wave conditions over a period of years at a particular location. The average wave conditions for a particular section of shoreline, can be misleading. An average annual wave height of two feet may be the result of many days of near calm separated by relatively few days of severe storms waves. More informative are statistics that show how often waves of particular heights and periods occur at locations of interest.

Lake Michigan shoreline at Lake Forest, Illinois, Fall 1986.

Wave climate statistics suggest the extent of extreme wave conditions, such as those associated with a 20-year storm. Such a storm is expected, on average, to occur only once in 20 years. There is a 40 percent chance of a 20-year storm occurring during a 10-year period and a 71 percent chance of such a storm occurring during a 25-year period of coastal property ownership. Wave climates (and wave climate statistics) shift as the climate changes.

Local Wave Conditions

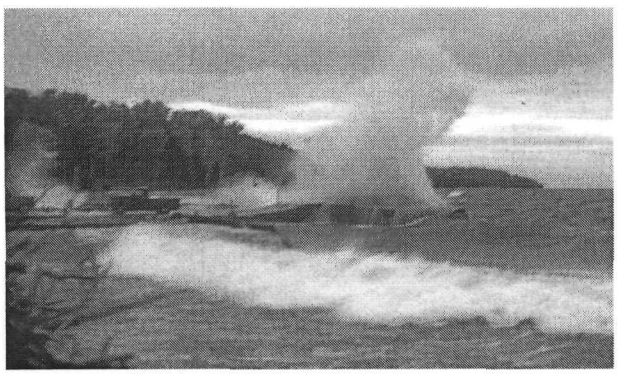
Shallow-water wave conditions depend upon deep-water wave conditions, nearshore obstacles in wave paths, depth of water and lakebed slope near shore. Wave direction and height can change as waves "feel bottom" and their paths bend (refract) due to friction from lakebed shoals or bars. Waves also bend (diffract) around points of land and ends of breakwaters, allowing waves to move behind such obstacles.

Fortunately for coastal property owners, shallow nearshore water depths are typical of most coastal sites; they cause much wave power to dissipate before it reaches land.

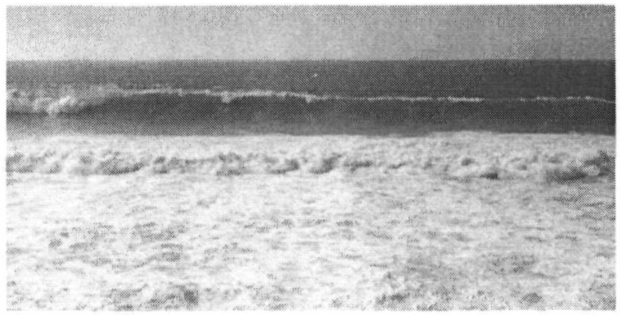
As large storm waves approach shallow water, they lose their power—first by partial spilling of the wave crests, followed by wave breaking and finally in wave runup on the shore. The wave power can be released gradually in spilling breaking waves running over gradually shoaling lakebeds or released suddenly in plunging breakers running over steeply shoaling lakebeds. Water depth limits the height of waves passing through shoal waters to approximately one-half to one times the water depth, depending on the lakebed slope and the wave characteristics.

Rising lake levels and/or lakebed erosion create deeper water close to the water's edge and allow more wave power to attack the shore. Falling lake levels have the opposite effect.

Coastal property may be protected from damaging breaking waves by unseen offshore shoals and/or a gently sloping lakebed that causes most of the storm wave power to dissipate before it reaches shore. Where deep water is closer to shore and the unseen underwater portion of the beach has a steep slope, large waves may reach and damage the shore.



Spilling breaking wave



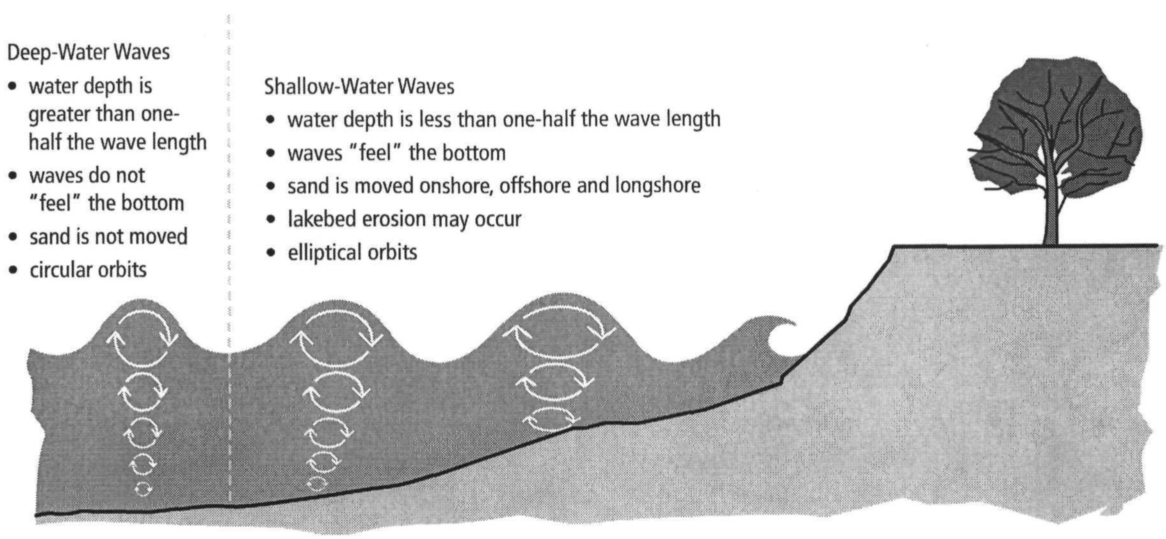
Plunging breaker

A trained professional is needed to estimate wave conditions.

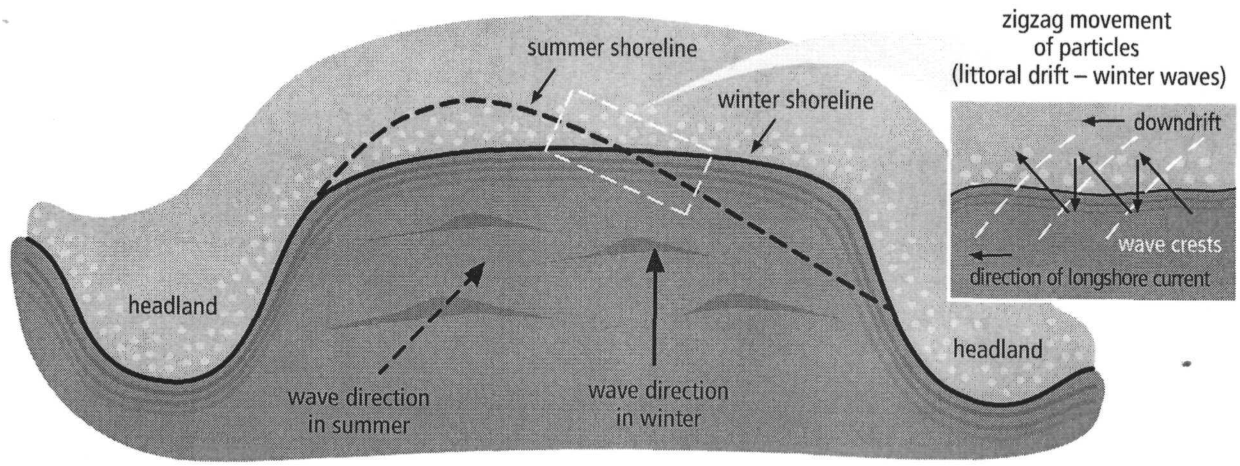
Local Water Currents

Strong winds and large waves drag some water towards the coast. Between the breaking waves and the dry beach, the water can be higher than the lake level. This elevated water will return to the lower lake level beyond the breakers either as return flow beneath the waves (sometimes called an undertow), or as currents that flow parallel to the beach as "longshore currents" before turning lakeward as "rip currents" to move offshore. The longshore currents and the rip currents are typically narrow streams moving at speeds of one to five miles per hour (0.4 – 2.5 meters per second).

The direction of the longshore current will usually be similar to the direction that waves are traveling as they approach at an angle other than perpendicular to the



Waves Feeling the Lake Bottom



Littoral Drift and a Shoreline Response to Waves

shore. When facing the lake, if the waves are approaching the breakers from the right, the longshore current is likely to be moving to the left.

Dangerous rip currents may occur where structures and natural features jutting into the lake alter the path of the longshore current.

Possible rip current locations include harbor breakwaters and jetties, long solid piers or groins, large shoreline rock outcrops or points of land, nearshore shoals and areas offshore of beaches with sand bars and troughs. Strong, dangerous currents can also be found at times in the armored coves or cells constructed to provide small, sheltered pocket beaches. Rip currents may be hard to spot. Look for a stretch of relatively unbroken water in a line of breakers, or telltale signs like patches (or lines) of foam or debris, or discolored water moving in a direction from inshore of the breakers to offshore. Once rip currents have formed, they cut troughs in sand bars and remain fairly stable until wind conditions change.

Sediment transport is the method by which dynamic coastline features, such as beaches, spits, dunes and offshore bars, are built and maintained.

Longshore and Cross-Shore Transport of Sediment

Littoral transport is nearshore sediment transport driven by waves and currents. This transport occurs both parallel to the shoreline (longshore) and perpendicular to the shoreline (cross shore or on-off shore).

Storm waves carve beaches, ridges and banks, transporting large volumes of sand to nearshore bars. Where the rate of offshore sand transport exceeds the rate of supply from updrift sources, the beach erodes. During calmer periods, waves transport sand from offshore bars and deposit it on the beach face. Through these cycles, there is a movement of sand and gravel along shore in response to the shifting directions and sizes of waves. In many places there is a net movement in one direction. The transport direction depends on such factors as wave climate, bathymetry, shoreline orientation, and the presence of natural or artificial features that deflect waves and currents. Cross-shore transport is affected by changes in lake levels.

The "littoral zone," where littoral transport occurs, extends roughly across the surf zone from where the waves begin to break near shore to the shoreline. Wave conditions and current speed determine the size of material that can be transported. The rate of transport within the littoral zone is relatively small along erosion-resistant rocky shorelines and along cohesive soil shorelines but may reach several hundred thousand cubic yards (a hundred thousand cubic meters) per year along some sandy coastlines.

Beach-building materials are mostly sand, gravel, and stone that enter the littoral transport system from dune, bluff and lakebed erosion along the coastline with additional material contributed by streams. Material may be blocked from entering the littoral system in many ways. Material from streams may be blocked by dams or removed from river channels and harbors by dredging. Littoral contributions may be blocked by shore protection structures. Sand and gravel mining and dredged material

Nearshore ice complex

disposal in deep water are additional ways in which beach-building material can be kept from the littoral system.

An understanding of littoral transport is important for predicting erosion trends and evaluating the possible effects of engineered coastal structures. Because coastline erosion supplies most of the material for littoral transport, deficits or surpluses of littoral material available to an area (indicated in a "sediment budget") are likely to result in changes in the erosion rate as well.

Beach-building materials are in many places prevented from entering the littoral transport system, resulting in diminished beaches and nearshore bars.

Ice on the Shore

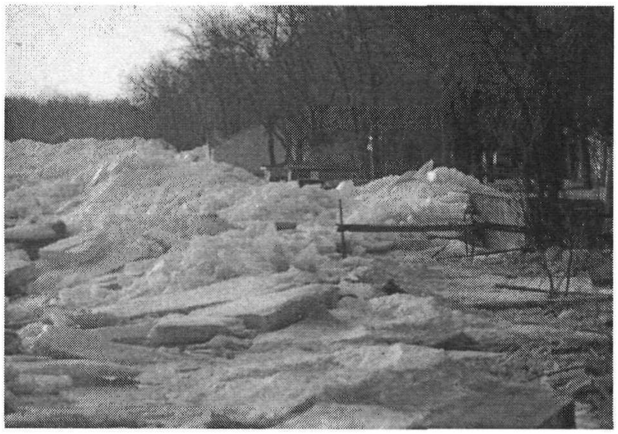
The type and amount of ice that forms along the shores varies from location to location and from day to day. A frozen beach is the first ice feature to form. Waves drive slush ice to shore to form an icefoot. On beaches exposed to waves, a nearshore ice complex forms, extending lakeward from the icefoot and containing relatively smooth sheets of ice. Ice ridges form where waves break, such as over nearshore sandbars, and provide a lakeward boundary for this ice mass. There may be several parallel rows of ice ridges; usually there are more ice ridges than sand bars. Lakeward of the ice ridges, a zone of slush ice may collect. This slush ice can be driven repeatedly by waves onto the outer ice ridge, raising its crest 15 feet (5 meters) high or higher above the lake. Ice ridges ground on the lakebed. The nearshore ice mass remains in place until warming air temperatures, wind and/or waves cause it to move or deteriorate. The ice mass may disappear abruptly during major storm events and can be destroyed and rebuilt several times during the winter.

Nearshore ice displaces wave energy lakeward, protecting the beach from wave-induced erosion, yet it may also contribute to erosion.

Waves breaking against grounded ice ridges scour the lakebed. The lakebed may be gouged by contact with the keels of ice ridges or "ice islands" moved by the wind (common on Lake Erie). Slush ice and anchor ice that releases from the bottom incorporate sediment. Drifting ice can transport significant quantities of sediment along and away from the shore.

An ice shove or ice push occurs when lake ice, moved by water currents or by wind (blowing over miles of ice), comes into contact with the shore. Ice is shoved up the shore away from the lake. Damage can result if the moving ice contacts structures, bluffs and banks. Ice shoves are unpredictable. The distance the ice moves onshore depends on whether the ice shove is a pile-up or ride-up event.

Pile-up occurs when the ice contacts an obstacle—an abrupt change of slope of the beach, or an existing ice ridge. The ice buckles and forms a large pile of broken ice



Ice shove

as the lake ice cover continues to fracture and contribute to the pile as it is driven ashore. Generally, an ice pile protects the area landward of the pile from burial by ice coming ashore. Ride-up tends to occur where a shore has a mild slope with no obstacles and is more likely to cause damage. The ice can be driven many feet (meters) inland. Ride-up often occurs in the early spring when an absence of nearshore ice masses and strong ice sheets creates favorable conditions.

Horizontal ice forces and ice damage depend on such factors as the surface roughness and slope of the ground or structure over which the ice is moving, properties of the ice, thickness of the ice, and the magnitude and duration of the driving force. Horizontal forces become highly slope-dependent for slopes of more than 40 degrees from horizontal. Most revetments have slopes with angles from horizontal of 20 to 34 degrees.

Moving ice, called ice runs, in the connecting channels between lakes damages unprotected structures. Ice jams (large accumulations of stationary ice that restrict flow) may also form, flooding low-lying land along the channels and rivers. Ice booms are placed in the St. Mary's River, in the outlet of Lake Erie at the head of the Niagara River, and on the St. Lawrence River. Ice booms are necklaces of large floating timbers, chained together and anchored on the riverbed. Ice booms help form a stable ice cover that reduces the frequency, severity and duration of ice runs in the rivers.

Ice also causes problems in protected areas along the shore. Piles supporting docks that are left in the water can be damaged by thermal expansion of the ice and by pile jacking. Over the winter, the ceaseless rise and fall of water levels causes a rise and fall of ice sheets. As the ice sheet alternately freezes to and releases from piles, the process pulls (or jacks) piles out of the lakebed, distorting and breaking pile-supported piers.

Shoreline Erosion

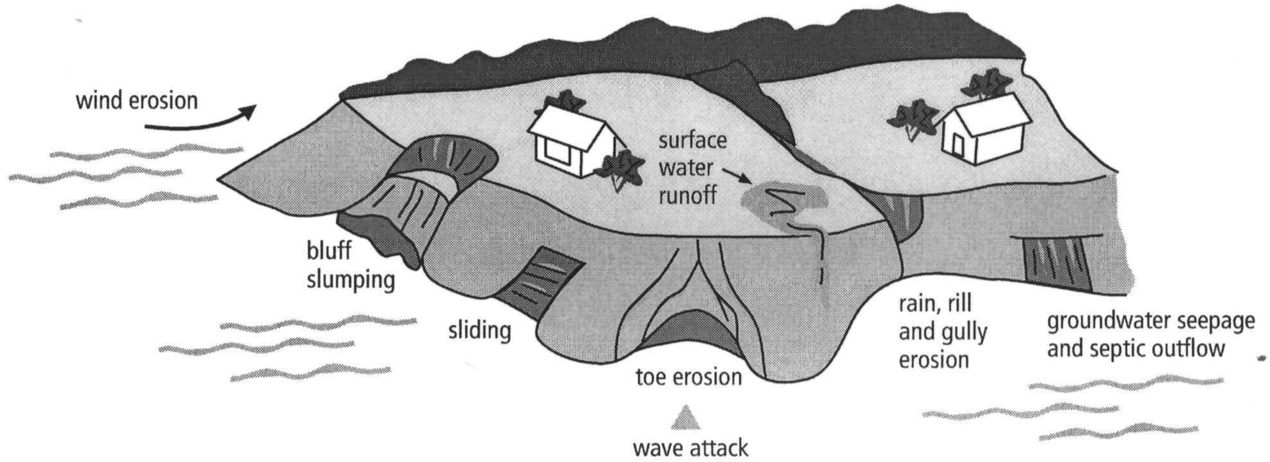
In the spring of 1985, owners of some low terrace properties on the Wisconsin coast of Lake Michigan were surprised when 30 to 50 feet (10 to 15 meters) of their front yards disappeared in one or two weekend storms. There are few exceptions to this retreat, although most are considerably less dramatic. Shores that have cohesive materials (clay, till and bedrock) have strong binding forces. Shores that have noncohesive materials (sand and gravel) have weak or no binding forces. Rock is the least erodible; sand and gravel the most erodible of these materials. One type of material may occur in a low bank, but several types typically occur in layers or mixtures within higher banks and bluffs.

In general, Great Lakes shorelines are retreating. They retreat at various rates—sometimes slowly and unnoticed, sometimes rapidly and alarmingly.

The erosion of a coastal slope occurs in response to storm waves attacking the slope toe, rising groundwater and instability in slope soils, surface-water runoff over the faces of slopes, and other factors. Contributing factors include soil composition; weathering of the slope face by freezing and thawing; vertical cracks in upper slope soil; steep slope; lake level; nearshore shoals and lakebed slope; storm wave energy and duration; amount of precipitation; shoreline ice cover; shoreline orientation; beach composition, width and slope; presence or absence of shore protection, and type of shore protection. Given enough time and a stable slope toe, erosion to a gentler slope and revegetation of the eroded slope face can produce a stable slope. However, in many places, wave erosion of the slope base (or toe) prevents development of a stable slope.

Erosion on rock shores typically involves rock falls where the toe of the slope has been gradually undercut by wave action. The rock above the undercut section remains relatively stable until erosion at the toe intersects a plane of weakness (or fault) in the rock, causing the failure of the rock slope. Rubble from rock falls forms temporary protection for the shore.

Sandy beach ridges, banks and beaches are sometimes the exception to the rule of retreat. Sandy shorelines



Causes and Effects of Coastal Erosion

advance and retreat as water levels rise and fall, storms come and go and sand supplies shrink or expand. Sandy shores tend to retreat in the face of high lake levels and storms as shore materials move offshore. Such shores may advance lakeward during times of low lake levels as mild winds and waves build beaches, ridges and dunes from nearshore deposits. Rebuilt ridges and dunes become significant reservoirs of sand. When storm waves erode the beach, these reservoirs of sand nourish the beach.

easily removed by abrasive particles under small wave motion. Lakebed erosion proceeds modestly, a few millimeters at a time. The weathering process occurs throughout the year and extends into water depths greater than 33 feet (10 meters).

The underwater erosion of the lakebed often controls the rate at which the recession of adjacent cohesive shoreline slopes takes place, allowing larger waves to reach the toe of the bluff and increasing rates of recession.

Erosion of the lakebed is a common feature along cohesive shorelines of the Great Lakes.

Lakebed Erosion

Sand or gravel in a narrow beach or present as a thin layer over an erodible lakebed acts as an abrasive, wearing away the lakebed under nearly constant wave motion. Measurements have shown rates of vertical erosion in the range of one-half to six inches (1 to 15 centimeters) per year in glacial till. More typical erosion rates are one to two inches (three to five centimeters) per year. Lakebed erosion rates tend to be highest close to shore where the waves break and cause turbulence. Erosion rates tend to decrease further from shore to less than 1/10th inch (just a few millimeters) per year in water depths of seven to nine feet (greater than a few meters).

A key feature of these shorelines is that when erosion of the nearshore lakebed takes place, it is irreversible—it cannot be restored as sandy shores can. The fine sediments are lost to circulate in the lake and settle out in deep water basins.

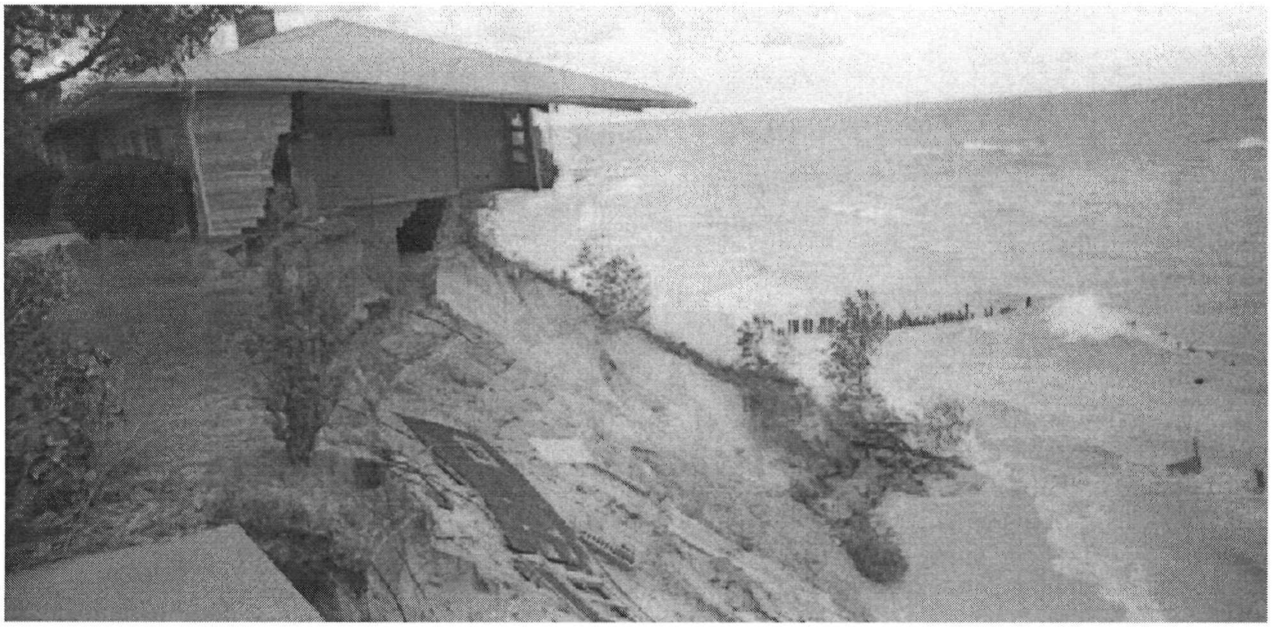
The strength of cohesive lakebed clays and tills is diminished by weathering. The thin weathered layer is

Lakebed erosion and bluff recession proceed in unison. The rate of vertical erosion on the nearshore profile is in proportion to the profile slope: the steeper the slope, the greater the erosion rate. An indication of lakebed erosion is the concave shape of most cohesive profiles with steep slopes close to shore where erosion rates are highest, and the slope decreasing offshore into deeper water where erosion rates decrease.

Lakebed erosion (or lakebed downcutting) also occurs on nearshore lakebeds of relatively weak bedrock such as shale and some sandstone.

Where lakebed erosion is occurring, any structure built to protect the toe of the bluff is subject to increasing wave energy and undermining of the foundation as the water depth in front of the structure increases.

In areas where strong bedrock occurs in shallow water, or an accumulation of cobbles and boulders forms a protective lag deposit over the cohesive lakebed, a nearly horizontal platform will develop, ultimately reducing the rate of recession of the bluff toe. A lag deposit is a



A house lost to erosion

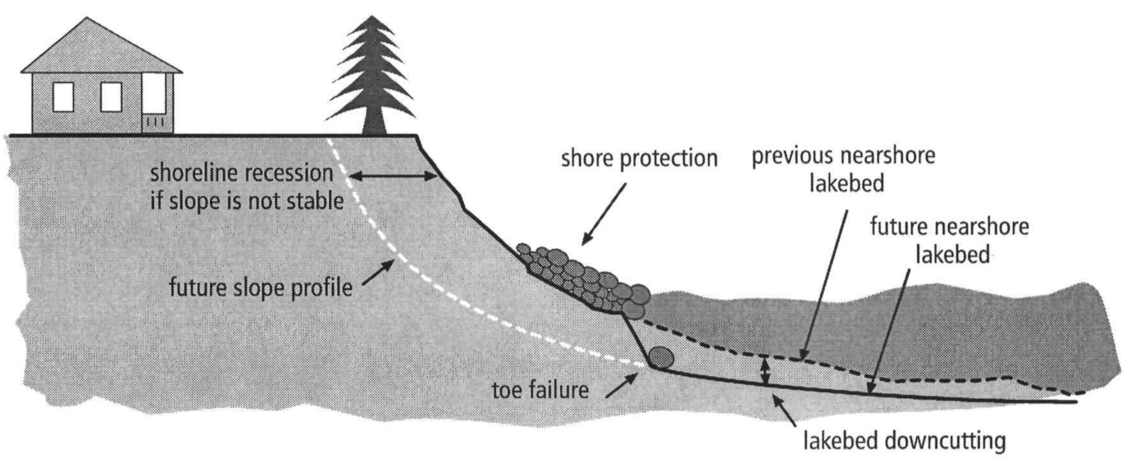
layer of stones left in glacial sediments after fine material is eroded.

During periods of low lake levels, the nearshore lakebed is subject to higher water velocities from wave motion, and the zone of wave breaking (where erosion is highest) occurs further offshore. When high water levels return, the water depth close to shore is greater than it was during the previous high water period, increasing wave impacts and erosion on the shore.

If recession of a coastal bluff occurs from wave action without lakebed erosion, then a shallow platform is left as the bluff recedes. Waves dissipate their energy on this platform, reducing the ability of the waves to erode the bluff toe.

How Stable Is a Shoreline Slope?

Erosion can be spectacular and threatening with sudden slumping and sliding of massive blocks of soil, or it can be subtle, significant, and undetected. Typically, cracks on the ground surface landward of the bluff edge or a slight drop in a section of a bluff or bank top is a warning that slope slumping is about to happen, or has started. The erosion of bluffs along the coast can be quite unpredictable. A bluff edge may not have moved



Lakebed Erosion with Slope Recession and Failure of Shore Protection Structure

Bluff failure at Klode Park, Lake Michigan

significantly in 40 years yet may lose 5 to 50 feet (1.5 to 15 meters), or more, next week. Bluff slumping can be triggered by wave or current erosion in the lower parts of the slope and the lakebed.

Landslide-triggering mechanisms on bluff slopes include intense rainfall or rapid snowmelt that quickly seeps into the bluff, causes a rapid rise in groundwater levels, adds to soil loads, and weakens soil strength. Sand layers and lenses sandwiched between soils that don't easily permit water to pass allow easy groundwater passage and discharge at the bluff face, which destabilizes the soil above the eroding sand layer.

There are opposing forces acting on a mass that may slide along a potential failure surface. Some bluffs are closer than others to sudden failure. The perceived state of stability against future sliding or slumping is commonly expressed as a safety factor (or factor of safety). A safety factor is the ratio of the forces resisting failure divided by the forces pulling down the potential sliding mass along the failure surface. Each soil has a maximum capacity to resist sliding or shearing, known as shear strength. A safety factor greater than one is good because it means that the forces resisting failure are stronger than the forces working toward a failure. Once the balance of forces (safety factor) is reduced to less than one, slope failure is likely to occur.

As the climate changes, changes in the frequency and intensity of storms and major precipitation events, and changes in the frequency and severity of freeze-thaw cycles, may bring soil conditions that will alter slope stability in ways that were not experienced by property owners during prior years of ownership.

Erosion can proceed undetected where slope soils are exposed. The strength of exposed till on slopes is weakened by freezing and thawing.

A geotechnical expert is needed to determine slope stability, evaluate erosion risk on properties with existing structures and select a safe setback distance for new construction. Coastal slope stability is highly variable from place to place around the Great Lakes, and soil characteristics and soil conditions may differ significantly on adjoining properties. Many properties depend upon shore protection structures to maintain the stability of the toe and face of the slope. The adequacy and durability of such structures can only be determined with professional assistance.

Water on the Land

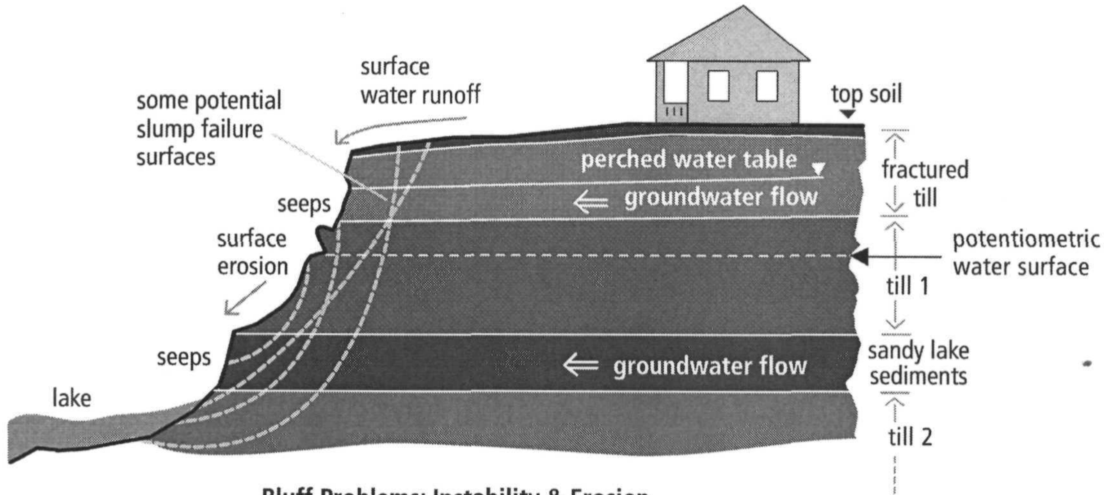
Water arrives on the land as either surface-water runoff or as groundwater. Some of this water originates on the coastal property. Other surface water and groundwater is flowing through on its journey to the lake from inland sources.

Surface-water runoff may come from rain water, snow melt, groundwater seeps or springs, and lawn or garden sprinkling systems. It may come from roofs through gutter pipes or from driveways, parking lots and roads. Surface runoff over the face of a coastal slope gradually loosens and visibly removes exposed soil on the slope, resulting in up to half of the loss of slope soils in some places. The volume of rain water, snow melt or artificially discharged water and the rate at which it arrives on the ground surface has a large influence on erosion.

signs of surface-water problems

There are a number of indicators of surface-water problems on and near coastal slopes. They include:

- Large exposed soil surfaces on the slopes
- Miniature troughs or larger gullies
- Exposed lengths of drain pipe
- Exposed foundations of stairways or other structures
- Areas of decayed vegetation in low areas
- Exposed soil surfaces on the land



Bluff Problems: Instability & Erosion
Surface Water Runoff Groundwater Seepage

Surface runoff from grass lawns is greater than runoff from grass lands and can be almost as great as runoff from paved areas. Water runs off steeply sloped land faster than gently sloped land. Low spots on land behind coastal slopes collect surface water. Land surfaces that are highly permeable allow water to penetrate the soil easily and cause less surface runoff but more groundwater infiltration than less permeable surfaces. Gullies or small troughs in the face of a slope channel surface water down the slope.

Groundwater infiltrates into the soils of coastal properties and moves to the slope face from surface water sources, off-site groundwater sources, septic systems or dry wells. The hidden activity of groundwater can be more dangerous than the visible effects of surface water runoff because groundwater can trigger large, deep landslides that sometimes have catastrophic consequences. The presence of water in soil pores and soil fractures beneath a slope weakens the soil by adding weight and by reducing the frictional resistance among soil particles that are in contact with one another. Groundwater flowing in a soil layer confined between two less-permeable layers (like till 1 and till 2 in the figure above) will rise in vertical wells to the potentiometric water surface (shown as a dotted line the figure above).

All coastal properties have groundwater flow beneath them; the ground adjacent to and lower than the lake surface elevation will generally be saturated. The surface of this zone of saturation (called the water table) is at lake level at the shoreline and rises gradually in the inland direction. For any banks consisting entirely of sand and/or gravel, this will be the only groundwater flow system present. Infiltrating water moves directly into the lake-level groundwater flow system and causes little weakening of the soil.

Many coastal bluffs contain soil layers (clays and tills) that retard water flow into the water table near lake level. Coastal landslide problems develop primarily where there are zones of water saturation above the lower, main water table; these are called perched groundwater tables. At such sites, groundwater collects in the sand and gravel layers because underlying soil layers that are resistant to flow slow downward movement of the water. The water flow in these sand and gravel layers is usually toward the slope face, where the water emerges in the form of seeps or springs.

Groundwater's influence on slope stability is controlled by several factors, including the quantity and distribution of groundwater beneath coastal property. The amount and rate of water infiltration is also important. The greatest infiltration comes from prolonged, slow application of water at infiltration locations. The soil moisture content and the soil structure's ability to pass water through the soil are also important.

Groundwater problems are most severe in times of greatest infiltration. Expect a bluff to be least stable during times of heavy precipitation or rapid thawing of significant snow cover. Some places, water tables can rise temporarily from several feet to tens of feet in a few days to a few weeks following a single intense rainfall or snowmelt. Significant water storage within a bluff can develop during cold periods when freezing of the surface soil on the slope temporarily blocks groundwater discharge at seeps or springs.

Bluff movements tend to follow seasonal cycles. Rates of movement tend to increase with the arrival of late fall storm events and the beginning of bluff surface freezing. A frozen bluff face causes a back-up of the groundwater into vulnerable perched aquifers. More rapid bluff movements continue through the winter while perched water tables remain high. Movement continues into the spring through spring rains, rapid snow melt, and bluff-face thawing that releases the excess perched groundwater through soil weakened by winter's freeze-thaw activity. The bluff-destabilizing effects of storm waves diminish during periods of low lake levels, but groundwater activity and bluff movements may persist.

signs of groundwater problems

There are some indicators that property might contain perched groundwater and be vulnerable to water-induced landslides. They include the following:

- Clay and till layers between the bluff top and the beach level.
- Wetlands near, or on, the property.
- Seeps or flowing springs emerging from the bluff or bank face.
- Indications of perched groundwater in driller's logs from water well drilling.
- Types of vegetation on the slope that require abundant soil moisture.
- A piece of the land near the top of the slope that is at a slightly lower elevation than the adjoining land surface. This could be evidence of the first movement in a bluff slump sequence that may lead to the eventual sliding of the slumped section into the lake.
- Trees and large shrubs on the slope leaning toward the lake.
- Linear shoreline-parallel "wrinkles" in grassy slopes that may be indications of a gradual creeping of slope masses towards the water's edge.

PROTECTING YOUR COASTAL INVESTMENT

The cost of living along the shore is higher than the cost of owning and using similar inland properties.

Along Great Lakes shores, there is a high demand for coastal properties, which drives up the price. There is a trend towards building much larger coastal homes than in the past. Premium coastal land is being used for high-density housing like condominiums, and for other large projects. These large investments require the best available professional help in deciding what steps to take to protect an existing or planned investment from the hazards of natural coastal processes. "Best professional help" usually means a geotechnical engineer or geologist trained in slope stabilization, an engineer trained in shore protection design, and a qualified marine contractor. It is often more economical and effective to plan a shore protection strategy with neighbors.

Coastal property is unlike inland property in one critical way: natural processes and forces work to remove the lakeside portion of the land.

There are some vital reference points needed to protect a present or planned coastal investment. They include elevations, setback distances and the depth of the lot.

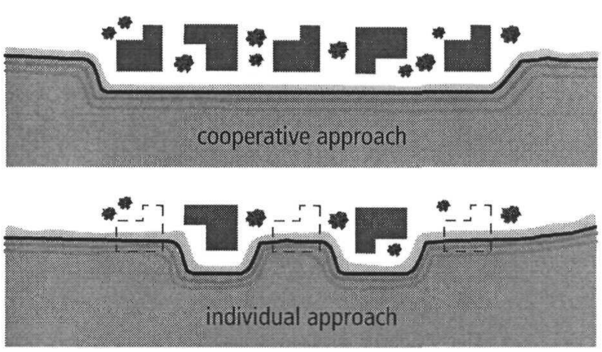
This section describes four options for protecting coastal investments: adaptation to natural coastal processes, restoration of natural defenses, moderation of the effects of coastal processes and armoring the shore. The environmental impacts of shore protection structures are described.

If you are considering the purchase of coastal property

The land resists erosion with natural defenses, including retreat. Some properties appear to have a stable lakeside edge with trees and other vegetation. However, vegetation only indicates stability during the lifetime of the plants and is not adequate for predicting the land's response to long-term changes. A large yard between the lake and buildings provides a buffer to protect the buildings from being undermined and destroyed as the land retreats. Using constructed shore protection to gain a close-up view of the lake is problematic and costly.

If you own a coastal property with one or more buildings on it

Your options are limited and your strategy for protecting your coastal investment will probably differ from the strategy used by a buyer of an empty coastal lot. If the lakeside edge of your coastal property has active erosion, the retreat of the land is shortening the useful life of your building(s). Adequate protection of your investment requires periodic monitoring of the condition of your bank/bluff/beach and shore protection and prompt corrective action when needed.



Protecting Your Coastal Investments

Knowing Where You Are on Coastal Property

Knowing where you are with respect to the lake will help determine the vulnerability of property to damage from extreme lake levels, storm waves and erosion, and the practicality of options for reducing that vulnerability.

The first set of key reference points are the elevations above lake level of: property, crest (top) of a shore protection structure, basement, and first floor of buildings. Lake levels are measured in feet or meters above or below a reference elevation called chart datum, or Low Water Datum (LWD), for each lake. Both terms are used for navigation charts and lake level forecasts. Chart datum is a handy reference to compare predicted lake level changes and storm wave runup with the elevations of land and structures. The land and structure elevations need to be converted to feet or meters above chart datum.

The second key reference points are the distances of structures from the lakeward edges of coastal slopes. These distances are called setback distances. They show how far structures are from a receding, or potentially receding, bluff or bank edge. The setback distance is one indication of the seriousness of an erosion threat to structures. Professional engineering assistance is needed to estimate setback distances that are adequate for future recession and for slope stabilization.

A third key reference point is the depth of a coastal lot—the distance from the landward edge of a property to the lakeward edge of a property. This distance indicates how much space is available to safely locate, or relocate, a building or other structure in order to gain an adequate setback distance and reduce the risk of damage and loss from shore erosion during the desired life of the structure.

Adaptation to Natural Processes

Adaptation is people adjusting to natural coastal processes by staying out of nature's way. It is a strategy of siting new buildings far enough from the edge of coastal slopes and high enough above the water that erosion won't claim them and flooding won't reach them during their useful lives. Adaptation is relocating existing buildings inland of erosion hazard areas and designing new buildings that can easily be relocated in case erosion is more rapid, or water levels higher, than anticipated. Adaptation does not mean moving building sites lakeward as lake levels drop and shorelines advance lakeward. In some situations, adaptation means passing up an opportunity to buy property where a building is threatened from erosion, or not constructing a permanent structure on threatened land.

Adaptation may be difficult if climate change brings lake levels beyond the design range used in building and operating lakeside power plants, water intakes, pumping stations, sewage treatment plants, industrial plants, and other infrastructure serving millions of people.

For lakeside residents, adaptation may work best at times of low lake levels where beaches, dunes and ridges rebuild as natural defenses against storms. When high water levels occur with more intense and more frequent precipitation events and periods of damaging storm waves, adaptation will be more challenging.

In such stormy, high water times, adaptation will be difficult for owners of large homes built close to slope edges and owners of older, smaller homes on small lots with few years left before erosion threatens.

Staying out of nature's way

A setback distance should allow for continuing erosion, formation of a stable slope once the slope toe has been stabilized, and some space for equipment to relocate a building if future slope failure jeopardizes the building. An expected recession setback distance is the expected future average annual recession rate multiplied by a chosen number of years.

Pick the time period during which you desire the building to be safe from failure due to erosion. Regulatory agencies that require a time-based setback generally use a period of 30 to 100 years. A well-constructed house may have a useful life of 70 to 100 years, or more. Act conservatively by using a setback that is greater than required. Historic recession rate information may not represent future recession rates, particularly with a changing climate. A building's location with respect to the edge of the bluff or bank at the time of sale will affect its value.

Staying out of nature's way includes identifying a safe setback distance from the top edge of a bank or bluff that provides protection from erosion for the expected life of the building.

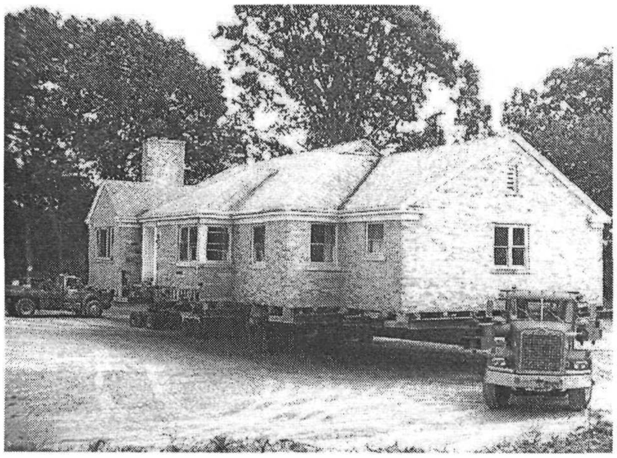
The view from the dwelling may be an important consideration. Consider building a gazebo or a readily moveable detached deck in a location lakeward of the house to provide the view.

Setback distances for buildings on properties with existing or planned shore protection structures should be estimated as if the shore protection structures were not present. Shore protection can fail—sometimes quickly and catastrophically. When this happens, the previously protected shoreline tends to recede rapidly toward the

safe setback distance

At least four factors should be considered when estimating a safe setback distance:

- The expected recession distance of the slope edge over the life of the building
- The height of the bank or bluff
- Stability of the slope
- The amount of room necessary to relocate the building if necessary



Relocating a house

position of neighboring unprotected shorelines, erasing the benefits gained from the former shore protection structure.

Relocating threatened buildings

Once a building is threatened with erosion damage, there are four options: do nothing and use the building until it needs to be demolished; sell the property and transfer the risk to the new owner; install bank/bluff and shore protection; relocate the building landward on site or to a new property. In many situations, relocation is the most cost-effective and certain way of increasing a home's longevity. This is especially true in bluff areas where shoreline stability is complex and erosion control is difficult. The cost and effort involved in relocation is extremely variable and depends on the characteristics of both the structure and the site.

Plan for possible future relocation when selecting a new building design and a location for the building on the property.

Plan for building relocation in case estimates of future recession rates turn out to be underestimates. The important structural elements that affect ease of relocation are foundation type, above-foundation framing, type of exterior siding, size and configuration of the building footprint, and presence of fireplaces and chimneys. Fireplaces and chimneys may require additional bracing, depending upon the design. Work with an architect, builder, and structural mover early in the design phase to ensure that all aspects are considered (see sidebar).

Relocating an existing building offers the peace of mind that comes when your building is a safe distance away from an eroding shoreline.

By reducing the hazard facing the home you can increase its value and decrease the need for costly slope stabilization and shore protection which may or may not work satisfactorily.

Contact a building mover to assess the project. Taking action before a building is undermined is important to ensure the feasibility of relocation. Movers may be reluctant to relocate a building perched on the edge of a bluff or bank. The moving cost depends on the characteristics of the building. It's less costly if the destination is on the same property. The cost will also depend on site characteristics. Is the terrain level enough and open enough to get moving equipment in and the house moved to a new site? For relocation on the property, it is important to have adequate depth on the lot roughly perpendicular to the lakeshore. The width of a building may present problems in a relocation due to obstacles located along the route.

Prior to relocation, certain agencies must be contacted for permits. Local professional movers know the

making relocation easier

Things to consider in making a proposed coastal building easier to relocate:

- It is easier to move a building with crawl spaces, basements, or pilings beneath the main floor than it is to move a building built on a slab.
- Buildings with stud frame walls supported by a floor joist system are generally easier to move than walls built of logs, concrete blocks, poured concrete, or solid stone.
- Buildings with exterior siding of wood, aluminum, steel, vinyl, brick, or stucco are generally easily moved .
- A building with the main floor on one level is easier to move than one constructed on multiple ground levels.
- Compact homes with rectangular footprints (ground area covered) are easier to move than are homes with large or irregular footprints.

procedures required. When looking at the project to determine costs, determine what it will take to bring the building to "turn-key condition"—ready to move back in.

Restoration of a Natural Shoreline

Restoration of a natural shoreline is bringing back natural coastal defenses against the processes that cause erosion. Restoration is nourishing and retaining beaches, revegetating beaches and slopes, reconstructing dunes and beach ridges, creating or restoring wetlands, and removing failed and failing shore protection structures. Where there are diminished supplies of sand and gravel for beach-building, restoration materials may come from upland sources such as sand and gravel pits. When low lake levels occur, most restoration activities should be easier to accomplish. Coastal wetland restoration may be an exception. Restoration efforts will be impeded by damaging storm waves riding ashore on high lake levels and by more frequent and/or more intense precipitation events.

Nourishing a beach

When the Great Lakes are in a period of low water levels there is an opportunity for natural shoreline protection features to rebuild and become vegetated.

Retaining and nourishing beaches

One major difference between cohesive and sandy shorelines is the ability of sandy shorelines to recover from erosion events. Beach retention is an important defense of coastal property against erosion by waves. Beach retention can be done by mimicking nature, creating miniature armored headlands, or by replacing lost sand and gravel with coarser, larger beach materials. Beach retention can be done on individual properties and in community-wide projects. Some methods of beach retention are mentioned in "Armoring the Shore" in this booklet. Permits are commonly required for both beach retention and beach nourishment projects.

Beach nourishment is one way to introduce needed beach-building materials into the longshore sediment transport system. Sand dunes and beach ridges (or foredunes) are important features along the shores of the Great Lakes. They trap windblown sand, store excess beach sand, and serve as natural erosion buffers.

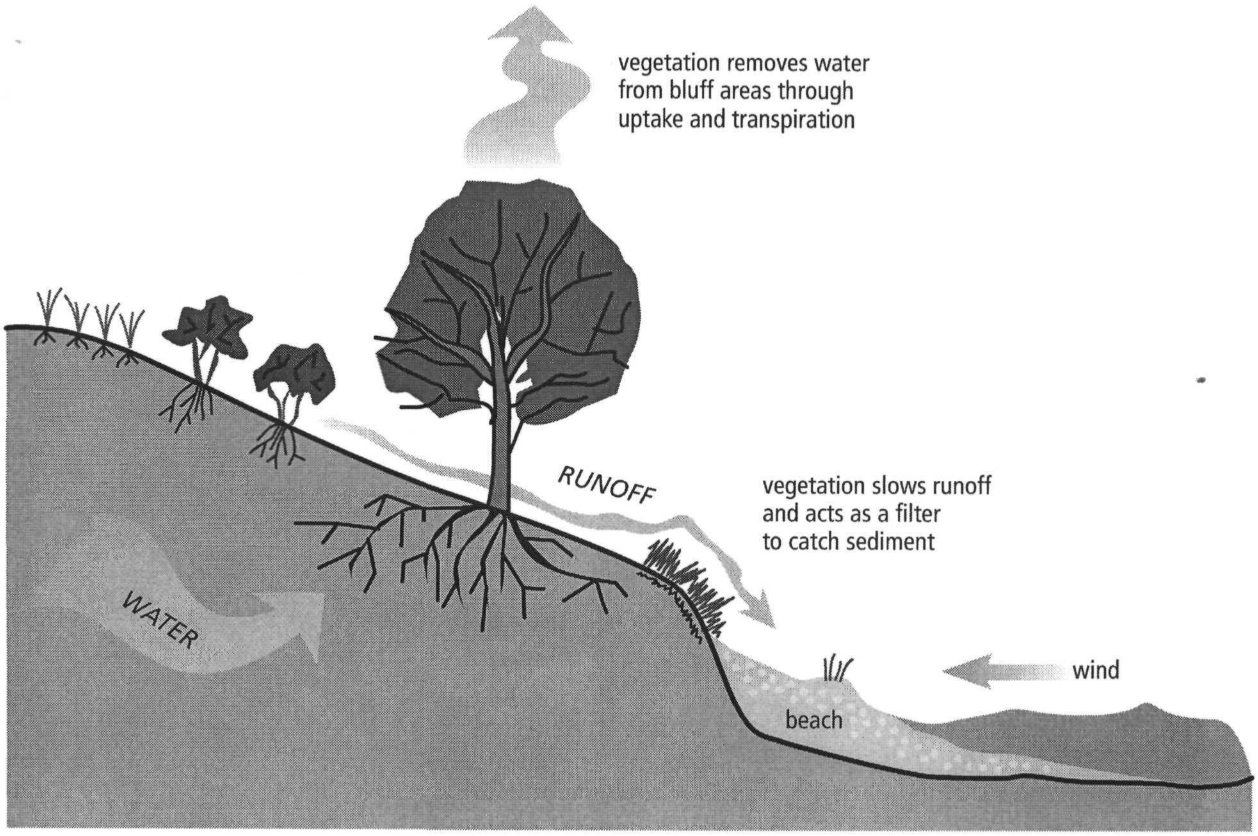
On the Great Lakes, beach nourishment is considered a means of sediment conservation. There are two main types of nourishment methods. One involves placement of "new" material trucked in from inland sources; the other involves reintroducing material that has been removed from the littoral transport system. The second type includes placement of clean, suitably sized dredged material on beaches or in nearshore waters. At some locations, littoral transport is a significant source of beach material, amounting to several hundred thousand cubic yards (a hundred thousand cubic meters) per year.

Revegetating the shore

Vegetation on coastal slopes stops surface erosion and may prevent shallow slides. Rising water levels and storm waves strip vegetation from shoreline beaches, beach ridges and eroding dunes. The natural establishment and growth of new vegetation is a key step in the rebuilding process of beach ridges and dunes. Cutting of vegetation to improve a view can have detrimental effects on slope stability.

Exposed soils on coastal slopes may need some help to become quickly revegetated and to stop surface erosion. Plant shrubs, grasses, and other ground cover.

Planting vegetation in Hamilton Harbour, Ontario

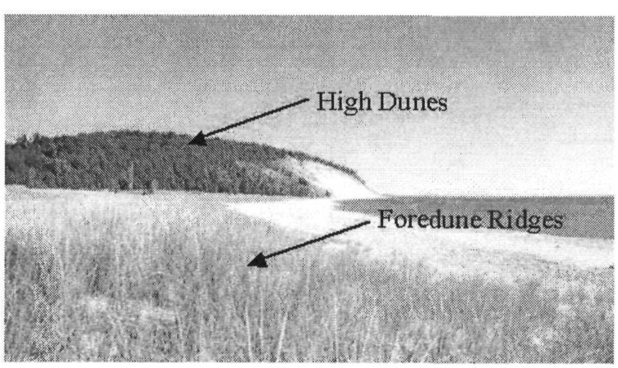


Revegetated Coastal Slope

Surface and shallow groundwater is removed from the soil by transpiration through plants, strengthening the soil. Deep-rooted vegetation that will help to stabilize the slope is preferred. Small trees that will not grow to be large trees are preferred because large trees cause large, concentrated loads on slopes, partially offsetting the added strength their roots provide to slope soils.

Constructing dunes and beach ridges

Low-lying foredune beach ridges are at the back of the active beach and closer to the water's edge than the dunes. The relatively higher dunes are landward of the beach ridges. The beach ridges are the youngest of the coastal sandy landforms. The high coastal dunes are typically older than the ridges and exhibit a more stabilized forest growth.



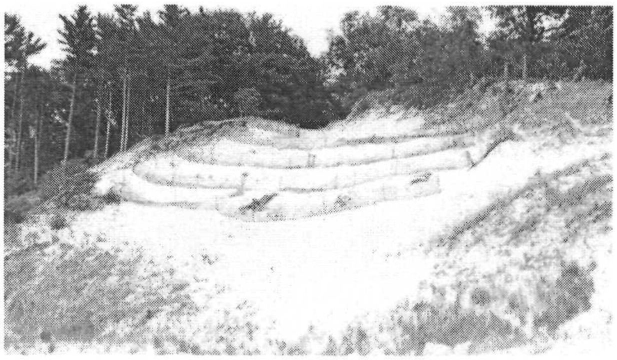
Typical coastal dunes

Property owners can use the natural forces that create these ridges and dunes to build (or rebuild) this environmentally friendly form of shore protection.

Beach ridge construction starts when an obstruction on the beach interferes with the wind, causing sand to accumulate. Two common methods for creating this wind interference are installation of sand fencing and planting of dune grass.

Fencing is a common means of trapping sand. A relatively cheap and easy fence to install is a slot-type snow fence, but other types of materials can also be used. Here are some basic guidelines to consider when installing sand fencing:

- Fencing should be about 50% porous.
- The fence line should coincide with the natural vegetation line.
- The fence should be roughly parallel with the shoreline.



Sand fencing

There are two common ways to build a dune or beach ridge with sand fencing. One is by installing one line of fencing and following it with another single fence as each line fills. The other way is to install double fence rows with the distance between rows roughly four times the fence height.

Dunes built using fences should be stabilized with vegetation, or they will easily erode away from wind and wave action. Using both methods together is an efficient way to build dune shore protection. Planting vegetation alone can also be a good way to create a dune. Before planting dune grass or installing sand fences, consult an expert on this subject.

There are a few species of plants that are recommended for use in the Great Lakes Region. To initiate the stabilization process, plant one or more of the following species:

- marram (dune) grass,
- wheat grass,
- wild rye,
- dune willows.

Once these plants are established and flourishing, plant the following species:

- sand cherry
- choke cherry.

Dune grass planting

After these plants are growing well, plant cottonwood and/or basswood to advance mature development.

The mentioned species are capable of surviving harsh beach environments and can weather drought, flooding, high surface temperatures and sunlight exposure. In addition, these species grow quickly through sand that has accumulated over them, and their vast root network helps stabilize the sand that they grow upon.

Installing pile-supported timber walkways over vulnerable sand ridges and dunes can also be helpful in protecting vegetation. Avoid walking through vegetated areas of sand dunes and ridges because the paths that develop lead to blow-outs and more sand losses from wind erosion. Wind erosion can be slowed by prohibiting the use of all-terrain vehicles (ATVs) and other vehicles on beaches, sand ridges and dunes; these vehicles destroy sand-anchoring vegetation.

Creating or restoring wetlands

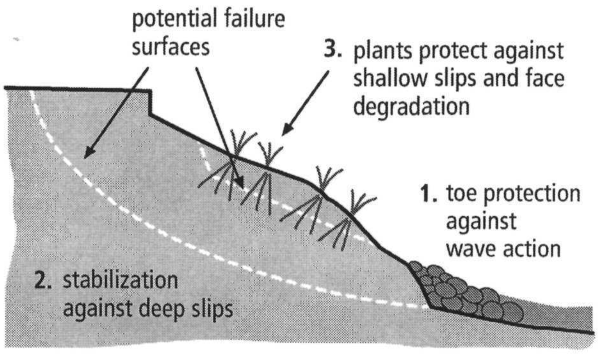
Great Lakes coastal wetlands are areas where water levels and land merge to form unique ecosystems that sustain a multitude of life. Coastal wetlands occur where there is some natural protection from high wave power. They absorb some of this power.

Coastal wetlands are a valuable buffer between the lake and upland areas. Restoring and preserving coastal wetlands requires understanding the processes that maintain a wetland, identifying the causes of degradation, and possessing the technical experience to formulate a plan. Wetland specialists should be consulted to ensure success in preserving and restoring these unique ecosystems.

Approaches to restoration can be either hydrological or biological. Hydrological remediation includes restoring hydrologic connections between lakes and wetland water bodies and restoring wetland water tables. Biological methods include control of nonindigenous plants and animals, increasing populations of native wetland plants and animals, and enhancing habitat through management of plant species that provide habitat or introduce constructed habitats.

Removing failed or failing structures

A walk along the beach is often hindered by abandoned or destroyed shore protection from a previous era—an overturned seawall, scattered remnants of a bulkhead or groin, pieces of concrete. Some of these failed structures and materials offer limited shore protection, but many are unsightly, a safety hazard and an obstruction to beach use.



Three Basic Bluff Stabilization Strategies

If a structure required a federal, provincial or state permit, it is likely that the permit included conditions for repairing, reconstruction, retrieval or removal. Permit conditions may also have included measures for mitigation of any adverse impacts caused by the project, such as interruption of sand transport or acceleration of erosion at adjacent properties. In some instances, failed structures were constructed prior to implementation of regulatory measures that included permits and permit conditions. In such cases, jurisdiction over these failed structures can be confusing and complicated.

It is important to understand your legal responsibilities for your existing shore protection structure, including a failing or failed structure, whether or not you have a federal, provincial or state permit for the structure.

Moderation of Erosion

This strategy involves slowing erosion and improving existing shore protection by managing water on the land and making coastal slopes more stable, tripping storm waves, paving the lakebed, and other measures. Erosion moderation probably works best in times of low lake levels. When storm tracks shift and bring more frequent and or more intense snowfall or rainfall, management of surface water and groundwater will become more important and more difficult. High lake levels, more frequent and stronger storms and storm waves will challenge a moderation strategy.

Making a bluff or bank more stable

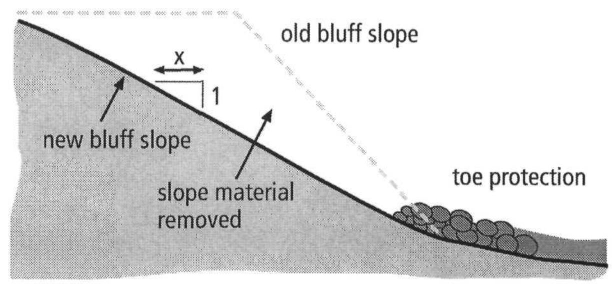
Toe protection is a form of armoring the shore and is described elsewhere in this booklet.

Stabilization against deep slips may involve different approaches depending on the conditions. Typical approaches involve some modification of the slope, making the slope less steep or buttressing it against sliding. Some examples are shown on this and the next page.

improving stability of slopes

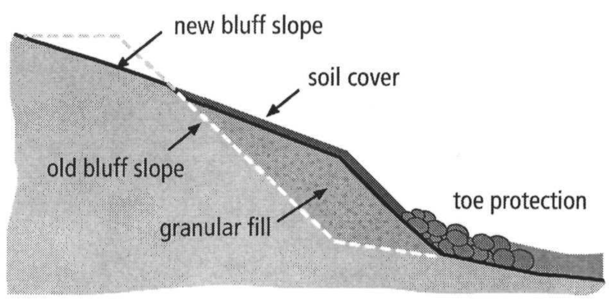
There are four measures that can be taken to improve the stability of slopes on coastal banks and bluffs. They are the following:

- Toe protection against wave action
- Stabilization against slope failure as deep slips
- Protection of the slope face against shallow slides and surface erosion
- Control of surface water and groundwater

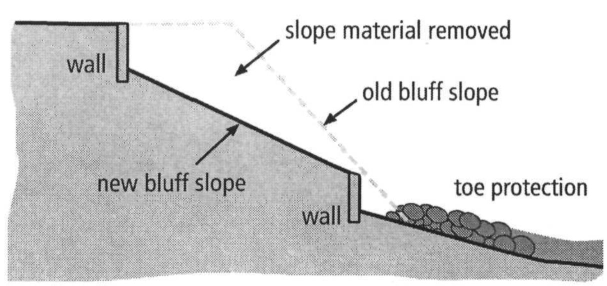


Cutback Slope Stabilization Method

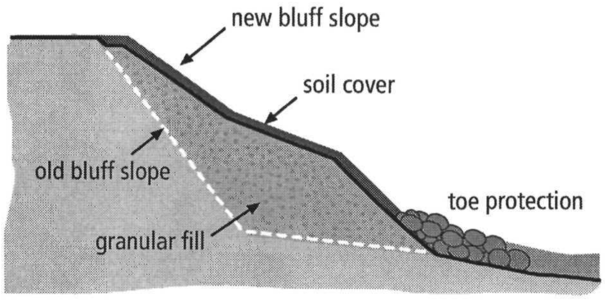
x:1 = Recommended stable slope ratio



Cut and Fill Slope Stabilization Method



Terraced Bluff Stabilization Method



Fill Slope Stabilization Method

Protection of a slope face typically involves providing vegetation, called soil bioengineering, and controlling surface-water runoff. Roots of plants enhance the stability of the surface of a bluff that is already stable against deep slips.

Managing water on the land

Surface-water management and groundwater management are in the first line of defense for protecting slope stability.

surface-water management

Surface-water management on a coastal property includes the following steps:

1. Collect surface-water runoff in a storm sewer or private drainage system.
2. Prevent surface water from running over the edge and down the face of a slope.
3. Avoid creating tilled gardens and flower beds of significant size near coastal slopes. These gardens and beds may become significant recharge areas for surface water to move into the groundwater flowing towards the slope.
4. Minimize ponding of water on land near coastal slopes.
5. Divert water from seeps or springs on the slope, collect and drain it from the slope.
6. Decrease the velocity of water flowing across coastal land in gullies to reduce the erosive scour potential of this water.

groundwater management

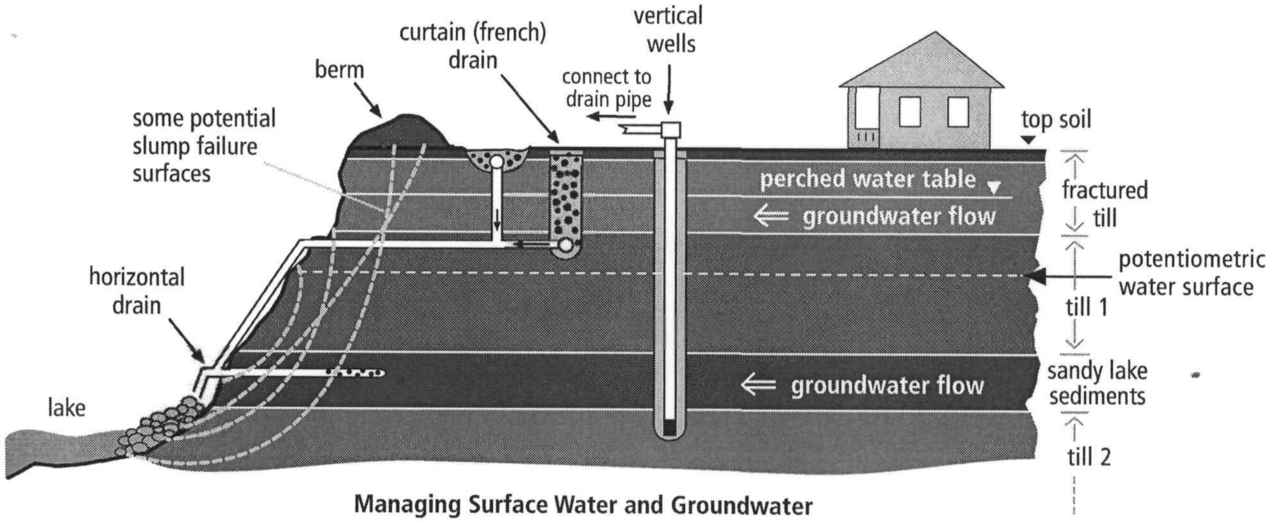
Some ways to manage groundwater flowing beneath a coastal property and towards a coastal slope:

1. In areas of new construction, or construction of new septic systems, leach fields should be located as far from the coastal slope as possible with discharge directed away from the coast.
2. Intercept groundwater flowing beneath the property and toward the coastal slope.
3. Remove groundwater from perched zones of saturation.

Professional advice and judgment is needed to anticipate how severe future precipitation events and conditions are likely to be and how best to manage surface water and groundwater on a coastal property.

It's critical to remove water from perched zones of water saturation beneath the property near the coastal slope and slope face in the places where future landslides could be initiated. Not all groundwater need be removed, only the excess water that could cause soil instability following future extreme precipitation events and extreme groundwater conditions.

There are several ways to drain the critical zone of groundwater. One way is to drill one or more rows of shallow, vertical wells roughly parallel to the edge of the slope. These wells can drain aquifer soil layers within the critical zone beneath the slope by pumping into drainage pipes. These wells can act as sumps: the pumps turn on only when perched water tables rise above levels established by careful analysis of the bluff failure system. Another way is to drill short, horizontal drains into the slope. Water in the perched aquifer layers within the critical zone beneath the slope will drain by gravity, discharging through pipes or tubes. Horizontal drains are favored by most geotechnical engineers because of their mechanical simplicity. If a bluff is experiencing significant slump displacement, horizontal drains can become distorted, damaged and ineffective if the movement persists. Trenches, drains and wells must be landward of all possible slope failure surfaces.



Managing Surface Water and Groundwater

Surface-water and groundwater problems on a coastal property may be local indications of much larger problems that affect multiple land owners.

Monitor changes in land development occurring landward and adjacent to the property. Roads, ditches, and residential/commercial/industrial developments can alter groundwater and surface-water flow to the detriment of coastal slope stability. Contact the developer responsible for the project and the government agency that regulates the development. The mitigation of water problems might require major construction.

Slowing wind erosion

Wind erosion can be slowed with vegetation, including "wind breaks"—trees and bushes that absorb wind energy. Avoid removal of portions of beach ridges and sand dunes to improve the view of the lake or to allow more convenient access to the water's edge. Such actions remove one of the natural protections of coastal property from wind and from storm waves. Removal of beach ridges and dunes may also be illegal, particularly where the ridges or dunes are lakeward of the public lakebed boundary.

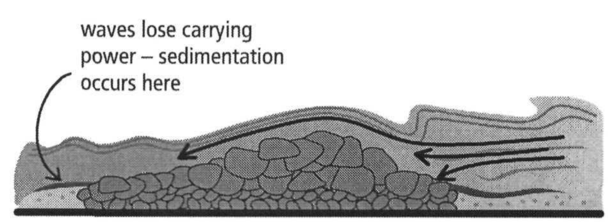
Improving existing protective structures

If a shore protection structure provides inadequate protection, or is damaged, there may be ways to improve the structure and lessen its adverse environmental impacts. Some structures with wave overtopping problems can be improved by constructing a stable, armored slope behind the structure that is designed to drain overtopping water without causing erosion. Another example of improvement is construction of an armor stone berm in front of the structure. Installations that have been in place for a few years should be investigated to see how well they have performed. Ineffective groins that are suspected of starving beaches along the coast should be dismantled. The materials may be useable in constructing other effective forms of shore protection.

Tripping waves

Wave energy approaching the shore can be reduced by "tripping" large waves before they reach shore, releasing much of their destructive power.

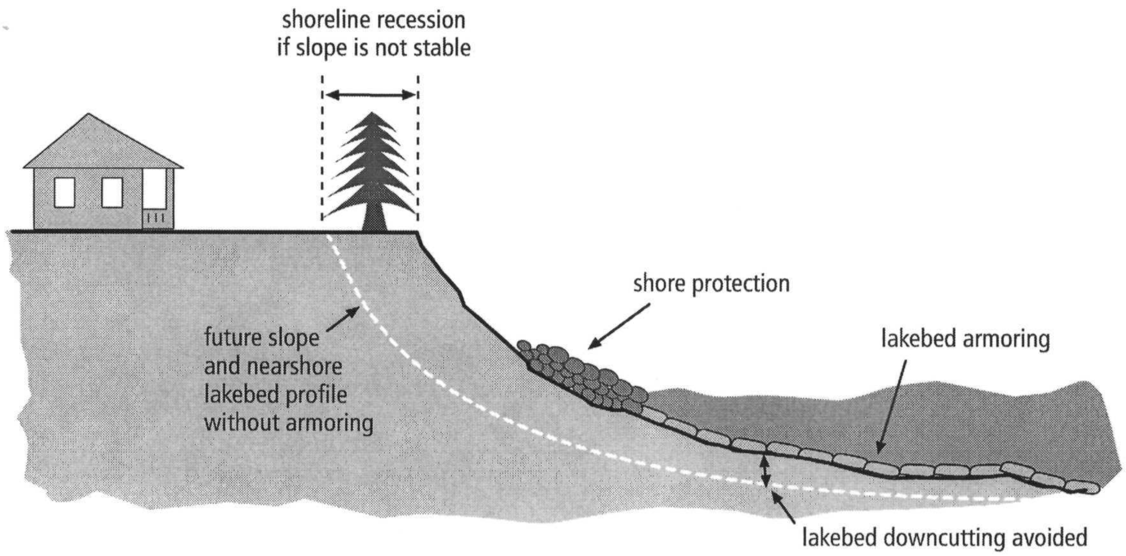
Waves can be tripped by building submerged breakwaters that are sometimes called artificial reefs, or by building nearshore shoals and bars. Such structures can be used to increase the fill life of renourished beaches. No general rules exist at this time for wave-tripping devices. Some of the features that need to be determined are the structure's design height, length, depth, possible hazards to navigation, and possible adverse impacts on neighboring properties.



Tripping Waves (Submerged Breakwater)

Armoring the lakebed

Lakebed armoring is the use of cobble-size stones to protect an eroding nearshore lakebed from wave energy. The stone is typically 6 to 18 inches (15 to 46 centimeters) in diameter and densely packed. If the paving protects the lakebed from downcutting, a shelf will form. As waves come in, some of their energy will dissipate over



Lakebed Paving and Shore Armoring to Protect Land from Shore and Lakebed Erosion

this armored shelf, improving the protection of the beach and the land behind it.

Lakebed armoring mimics some natural lakebeds where the glacial till contains boulders and cobbles that remain as "lag deposits" after the soft clays and sands have eroded. These lag deposits may armor the lakebed from further erosion by waves.

Lakebed armoring has been done on an experimental basis in the Great Lakes. The stability and life of this type of erosion moderation are still unknown. There is the possibility that nearshore lakebed habitats could be affected in positive or negative ways.

Armoring the Shore

Armoring the shore is an option of last resort. Armoring is a strategy for land with vulnerable buildings that would be extremely expensive or impossible to relocate once they are threatened by erosion or storm wave overtopping—large coastal homes, power plants, industrial plants, etc.

Armoring may be needed when climate variations bring periods of high lake levels and storms of greater frequency and/or intensity. During periods of low water levels, construction of shore protection is easier and allows better placement against erodible bases of coastal slopes, deeper foundations, and better placement of toe protection. Storms of greater frequency and/or intensity than structures are designed to withstand are likely to cause unexpected and premature failures of structures. If climate change brings more freezing and thawing cycles during the winter, there will be more rapid disintegration of poor quality armor stone in shore protection structures. Cracking of some armor stone by freezing and thawing is a serious problem in the Great Lakes Basin.

The purpose of shore protection structures is to make the land more resistant to erosion and to protect upland facilities from damaging wave action. Most structures protect only the land directly behind them and have no beneficial effects on adjacent shorelines or on beaches lakeward of them.

Flexibility is a feature of armor stone, or rubble, structures. It is the ability of a structure to shift in response to wave forces or changing foundation conditions and retain structural stability.

Revetments

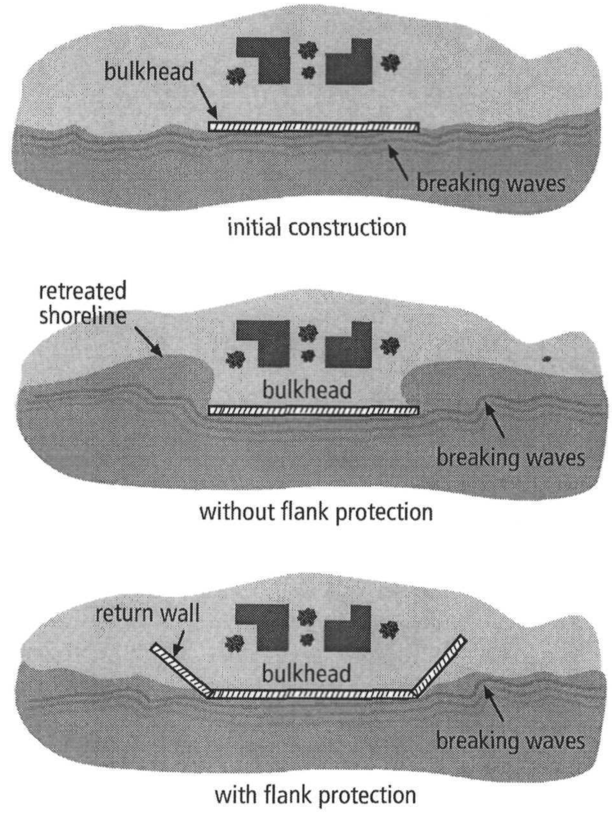
Revetments are probably the most-used shoreline-hardening structures in the Great Lakes and are the easiest type of shore protection structure to construct. A revetment is a shore-parallel structure with a sloping face, designed to protect the bank or bluff of a shore against the erosive attack of waves and/or currents.

Revetments generally consist of one or more protective outer (armor) layers of dumped or placed materials

shore armor

Common features of shore armor include:

- **Length.** The length of the structure is determined by the length of shoreline to be protected and the length of the return (or tie-in) of the ends of the structure back into the upland area to protect them against flanking.
- **Height.** The height of a structure above a lake level or a fixed elevation is determined by the expected wave height, wave runup and degree of protection against water overtopping desired.
- **Depth.** The depth to which the base or bottom of a structure penetrates the beach.
- **Shape.** The shape of a structure is the profile of its face. Shapes include vertical, sloping, convex, concave, and stepped.
- **Surface Texture.** The texture of a structure's face plays an important role in affecting wave runup and scour. The more irregular the texture, the greater the reduction in wave runup, overtopping and scour.
- **Permeability.** The ease with which water can flow through a structure. Permeability allows structures to absorb wave energy and reduces wave runup, overtopping and scour.
- **Toe Protection.** A lakeward projection of a structure that protects its foundation from undermining and scour by wave action.



Example of Flanking and Return Walls

(rock, manufactured concrete units, etc.) and a transition layer between the original soil and the protective armor that is intended to minimize loss of the soil beneath and behind the structure. A rock armor design may allow for some rock movement and "self-healing" following movement or loss of some armor stone on the slope.

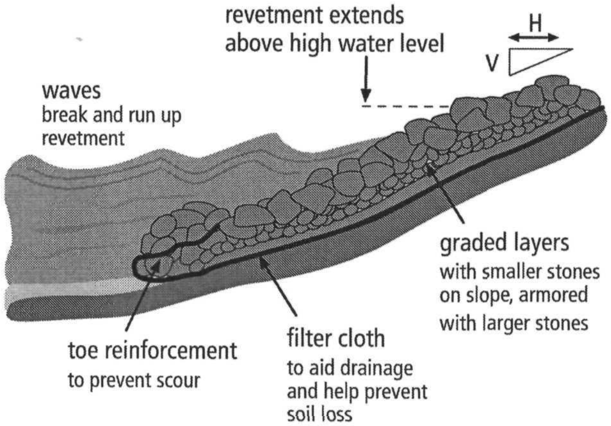
The lower the slope angle from horizontal (the more gentle the slope), the less scour is likely to occur in front of a revetment. The ability of sloping surfaces to reduce wave overtopping depends on slope angle, surface texture and structure permeability, plus height. Surface roughness and permeability on a revetment can have a significant positive effect in reducing wave runup, overtopping and scour.

The design of the outer protective armor layer is critical to the success of the revetment. It should be designed on the basis of extreme wave conditions, not average wave conditions. If the armor layer is rock, generally two or more layers of high-quality rock are needed. Rock is good at dissipating wave energy and reducing wave runup.

The transition layer may consist of one or more "filter layers" (stone smaller than the protective layer) and placement of a filter cloth directly against the native material. The filter cloth will prevent the native soil from being transported through the revetment and lost.

The toe and flank protection are critical elements that protect the structure from wave and end scour that could cause the revetment to collapse. The ends of the structure need to be protected from erosion moving around and causing structural collapse at either end.

Revetments should be constructed on relatively gentle slopes, about 1:2 to 1:4 (vertical rise to horizontal run). A 1:1.5 slope may be feasible if an engineering



V:H describes the slope

Typical Revetment Profile

analysis proves that the revetment will be stable during extreme storm and water level conditions.

For stone revetments, the quality and durability of the stone making up the protective layer is a key consideration, particularly in the sub-freezing winter environment of the Great Lakes. Fracturing of armor stones by freeze-thaw action over the winter months can greatly reduce the useful life of a revetment. Stone selection should be undertaken by a qualified geologist or engineer. For concrete structures, high-density/high-quality concrete with internal steel reinforcement provides additional resistance against abrasion by sand and gravel moved by waves, as well as protection from breaking during minor unit movement by waves.

revetment design

Revetment designs should provide adequate information, including details about:

- Armor layer
- Transition (filter) layer
- Structure toe
- Flank protection
- Revetment slopes
- Quality and durability of armor materials
- Plan for inspection and maintenance

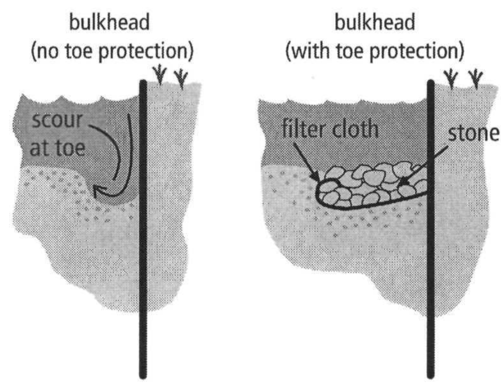
Inspection and maintenance of the revetment is required in order to ensure continued successful performance. Cracked armor stone needs to be removed and replaced with good stone (preferably stone that has aged three or four years). Inspections should be carried out annually and following large storm events.

Seawalls

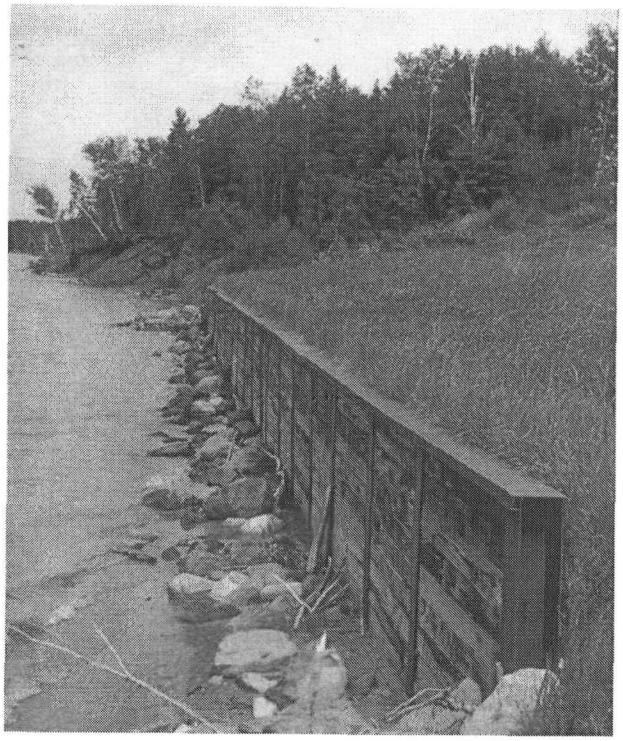
Seawalls are shore-parallel structures consisting at least partly of a vertical surface facing the water. The primary purpose of a seawall is to protect the land and property behind the wall from damage by storm wave action. Its secondary purpose is to prevent the land from sliding onto the beach or into the water. Seawalls require drainage or weep holes through the structure to relieve excess water pressure from the landward side. Seawalls tend to be more vulnerable to wave scour at the toe than are revetments because they tend to reflect more wave energy.

Seawalls may be cast-in-place or pre-cast gravity structures that rely on their own weight (and/or anchoring systems) to maintain their upright position. The land or fill behind them may contribute limited structural support. Seawalls may be smooth- or rough-faced and have various face shapes or combinations of shapes. They can be built as solid structures to reflect wave energy or as porous structures to absorb some wave energy within the structure. Seawalls may be constructed of a wide variety of materials and combinations of materials. Concrete, steel sheet pile, timber, and rock-filled timber cribs seem to be the most popular materials.

Massive, cast-in-place concrete seawalls can provide reliable and long-lasting protection from storm wave attack. They are usually used where a high degree of protection is required for high-value facilities and improvements. These seawalls may be of any size, large or small, and can be designed with any face shape, but they will



Example of Wave Scouring at Bulkhead



Seawall on Lake Superior

usually have faces that are relatively smooth in texture. Sometimes they have stepped faces.

Some seawalls are constructed of pre-cast concrete parts in easily-handled sections. These parts are often cast as concrete cribs, with solid sides and bottoms and a solid front in the desired profile shape. The back may be solid or omitted, depending on the engineering and design requirements. Pre-cast concrete seawalls are especially suited to applications where protection from low to medium wave action is required. The advantages of pre-cast units are rapid and relatively easy installation. Disadvantages include the possible scouring, undermining and settling of the individual units.

Seawalls may also be built like bulkheads to provide limited protection from waves. These walls are made of upright sheet materials with the lower portion of the sheets driven into the lakebed and a system to anchor the portion above the lakebed. Typical sheet materials for bulkheads are wood (generally pre-1960s) and steel. Usually the anchors are tie rods extending from the sheeting landward to piles or horizontal logs buried in the land behind the bulkhead.

Groins

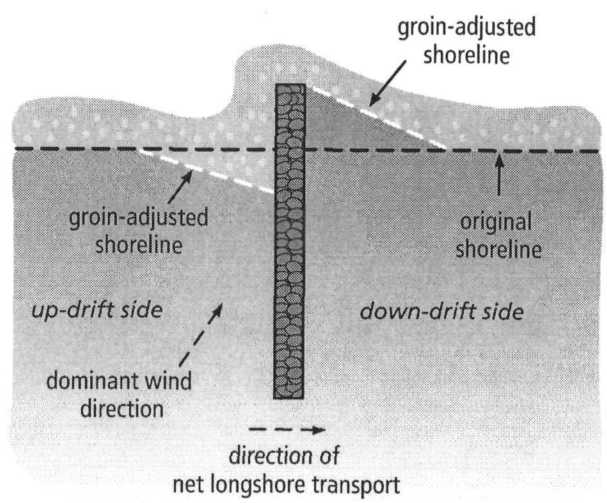
Groins are shore-perpendicular structures designed to stabilize a beach by holding beach material in place. Groins also trap sediment carried alongshore in the littoral transport system.

Groins can be used singularly or as part of a system (groin field), and they can be constructed of various materials, such as steel, rock, timber or concrete. On Great Lakes shores, groins are generally between 25 and 100 feet (8-30 meters) in length.

The main design features that affect groin performance include height, length, permeability, and spacing between groins. Impermeable high groins do not allow sediment to pass through; permeable groins have structural gaps that allow sediment to move through the structure. It is difficult to design groins that allow sediment to flow through portions of the structures.

Determining the best length of a groin is also difficult. Because the majority of sediment moving along a shore is found between the shoreline and the first sandbar, a groin that reaches the first bar will usually build a substantial beach up-drift but will also have a significant, negative down-drift impact. Determining groin length based on sandbar location is complicated due to the seasonal migration of sandbars.

Groin spacing of two to three times the length of the groin is generally recommended. Groins that are spaced too closely cause sediment to bypass the compartments between groins. Spacing groins too far apart allows erosion of beach material between the groins.



Beach Response to a Groin

The effectiveness of groins in protecting shorelines has been debated for a century and continues. Groins can work effectively where there is abundant sand and gravel moving along the shore and where the spaces between groins are kept filled so that most of the littoral material in the longshore transport passes by the groin or groin field to nourish other coastal properties down the shore. Some agencies require property owners to maintain adequate beach fill in the compartments between groins.

Waves, high water levels, and a lack of sediment supply limit the effectiveness of groins. Groins cannot prevent sediment movement offshore by storm waves. Sediment moves offshore during periods of high water and storms, emptying groin compartments and rendering the groins ineffective when they are most needed. As wave direction changes, the direction of sediment transport changes and may cause the groin(s) to lose material that had earlier been retained. Sediment supply is a critical factor in the functioning of a groin. Climate variations can bring a reversal of the dominant direction of longshore sediment transport and lead to a loss of beach material trapped by a single groin.

The role of groins in the Great Lakes may diminish to occasional attempts to hold a nourished beach in place. Lack of sand and gravel in transport along Great Lakes shorelines hinders groin function. The negative environmental impacts of groins makes their use controversial.

Breakwaters

Breakwaters are built to create areas of sheltered water, reduce the amount of wave energy eroding shorelines and help stabilize beaches. These structures can be located offshore or connected to the shoreline. A set of breakwaters may be connected to shore with steel sheetpile groins to retain artificially created beaches for recreation and shore protection.

Breakwaters are used to protect large properties with long shorelines, or to protect many properties in a community. A typical breakwater is a large structure that influences the shape of the shoreline for several hundred feet (a hundred meters) on either side of the structure and landward of the structure.

A common type of breakwater is the rubble mound structure. The structure has three layers: rock fill core stone, an under layer to prevent the core stone from moving and to provide seating for the armor layer, and armor (outer) layers to absorb and dissipate the oncoming wave energy.

Breakwaters for captive beaches at Lake Forest, Illinois

Experienced designers shape a breakwater to fit the purpose and environment of the site. The predicted maximum water level range, water depths, lakebed soil properties and conditions, extreme wave conditions, and currents affect the design. Key to the integrity and long life of the structure are the geometry, quality of construction, and durability of the material. Geometry includes the height and length of the structure, slope, sizes of stone, and toe protection details. The quality of construction depends upon the quality and placement of the stone material, especially the armor stone. Freeze-thaw cracking of armor stone threatens the stability and effectiveness of many breakwaters. The amount of contact between adjacent stones and a high degree of interlocking of the armor are crucial for good long-term performance.

Regular monitoring and prompt maintenance of breakwaters is very important. For breakwaters that have been well designed, well constructed and properly maintained, a 25-year design life can be achieved, and in some cases the structure can function as long as 50 years.

Unsuitable shore protection

There is a never-ending search for low-cost or more effective shore protection. It's common to try to make shore protection structures from readily available materials. Many kinds of shore protection devices have been tried that are generally unsuitable for shore and wave energy conditions on the Great Lakes (see sidebar). In the hands of skilled, experienced professionals, some "unsuitable materials" may be suitable for shore protection in conjunction with other measures.

Junk shore protection

Junk shore protection is material that is commonly found in recycling centers, junkyards, or landfills. This material is always unacceptable for shore protection (see sidebar). Some of this material may be toxic to aquatic organisms or become hazardous to swimmers on site and down the coast as the materials move off site.

Proprietary shore protection systems

Proprietary shore protection devices are structures and structure designs that are owned by particular individuals or firms. They are usually patented. They can be effective in a proper environment. However, in the wrong situation, proprietary devices (like other shore protection systems) may not provide adequate protection, or they may increase erosion problems. It is reasonable to expect marketers of such systems to provide substantial evidence for their performance claims. Get a second or third opinion from experts who are not involved in marketing these products.

Most proprietary shore protection systems are based on the same concepts or ideas as historically common shore protection methods. Proprietary shore protection systems may offer new technology, new materials, new installation methods, or new forms that mimic these concepts. An independent professional coastal engineer should be consulted when seriously considering a proprietary system. This expert can give an unbiased opinion on whether or not a proprietary system can work for a particular situation.

unsuitable shore protection

Shore protection devices that are generally unsuitable for the high-energy open coast environments of the Great Lakes include:

- Revetments formed of stone or concrete pieces light enough for a strong adult to lift
- Seawalls formed of softball- to basketball-sized stone in wire baskets
- Seawalls made of concrete blocks
- Seawalls made of vinyl sheetpiling in areas with heavy shore ice
- Plastic strands or plastic nets intended to build and retain beaches
- Plate-like concrete rubble from construction demolition
- All-timber bulkheads made of materials purchased at typical building supply stores
- Seawalls made of discarded sewer pipe.
- Sheet pile walls that don't sufficiently penetrate the lake bed
- Sand-filled bags

junk shore protection

Junk shore protection includes:

- Old cars and parts of cars
- Steel or plastic drums
- Concrete rubble with reinforcing rods or wire
- Wooden pallets
- Steel bedspring frames
- Concrete pours from cement making
- Plastic fencing
- Scrap steel parts, including wire
- Stone-filled grocery carts
- Cast-iron steam radiators
- Stacks of fiberglass sinks
- Rubber tires, loose or bound together
- Appliances
- Barges scuttled in nearshore waters

Environmental Impacts of Shore Protection Structures

Shore protection structures are intended to have an effect on the coast—to stop erosion of uplands or to stop erosion of beaches or both. Shore protection structures can have beneficial impacts by stabilizing beaches and by preventing shore land retreat behind the structures. Shore protection structures are controversial and can impact the shore in undesirable ways. A limited ability to predict the long-term impacts of such structures on other shoreline properties is a concern for designers and for the owners of the structures.

Construction activity in building such structures has temporary, negative impacts. Equipment damages or destroys vegetative cover, beach and nearshore habitat.

The activity may cause short-term and local increases in water turbidity.

Many shore protection structures replace natural, area-based shore defenses with linear defenses. One problem with this substitution is that the area-based erosive attack of storm waves may require an area-based defense.

Natural shoreline defenses break storm waves and absorb their power over the broad areas of shoals, barred lakebeds and beach slopes before the destructive waves reach the highly erodible faces of coastal upland slopes. During storms and periods of high lake levels, some of the mobile material is borrowed from the beach as the defenses are rearranged. When waves subside and water levels drop, the borrowed material may be returned to the beach. Losses of mobile materials are made up by new supplies, unless people, or nature, interfere. Other area-based defenses include bedrock outcrops near shore and on shore.

A negative impact common to all shore protection structures is that the intentional halting of erosion landward of the structures robs the littoral transport system of beach-building materials—sand, gravel and rocks.

Constructed, linear defenses are intentional barriers to the offshore movement of upland beach materials, blocking one of the natural responses to wave attack. Near these barriers, mobile materials are "borrowed" from adjoining unprotected shore slopes, beaches, and the nearshore lakebed to respond to wave attack in front of the linear structures. This borrowing makes neighbors' unprotected coastal properties more vulnerable to damaging wave attack.

Where shore protection structures mimic nature, the defense is like an area-based defense. Examples include confined and maintained beach nourishment, lakebed armoring, armored mini-"headlands" and captive beaches, and submerged nearshore breakwaters.

The negative effects of shore protection structures tend to be greater for structures that are perpendicular to shore than for shore-parallel structures. The negative effects tend to be less for structures landward of the active beach than for structures in the water or at the water's edge. The negative effects also tend to be less for permeable structures than for impermeable structures. The magnitude of a structure's interference with natural sediment movement increases with the length of the structure. An experienced professional is needed to design a structure appropriate to site conditions that maximizes performance and minimizes adverse impacts to client's and neighbors' properties.

Impacts of groins

Modern engineering practice is to combine groin construction with beach nourishment. The intended purpose of a groin or groin field is the retention of beach material, in order to widen or maintain the width of the beach without depriving down-drift properties of beach-building littoral material. The practice is also to keep groins and compartments between groins filled.

There is a short supply of experience in designing groins and groin fields without negative impacts. Negative local and distant impacts include a narrowing of down-drift beaches, an increase in down-drift erosion, and increased lakebed erosion. Groins that are not maintained in a filled condition have beach material accreting on the up-drift side of the barrier with a net loss of beach and nearshore material affecting multiple properties on the down-drift side. The higher and longer a groin is, the more material is captured and the greater the impact on adjacent beaches. The impacted shoreline may continue to lengthen long after construction has been completed. The placement of one groin often leads to the need for another. Before long, a series of groins forms a groin field that will take longer to fill, cause a greater disruption to longshore sediment transport and increase the cumulative effects on properties down the coast.

Negative impacts of groins can be reduced by using short, low-profile groins no higher than the designed or natural beach elevation to allow for overtopping and bypassing of material to the adjacent shoreline. Impacts can be reduced by locating the water end of a groin landward of the shoreward boundary of the breaker zone at high water levels. Frequent changes in direction of longshore transport, changes in water levels, and the erosive nature of storm waves on the Great Lakes combine to empty groin compartments, requiring refilling or increasing negative impacts.

Impacts of seawalls and revetments

The best chances for seawalls and revetments to work with minimal adverse environmental impact is where the structures are placed at the intersection of an upland slope and a broad sandy beach, and where there is a gentle nearshore lakebed slope with abundant longshore transport of sediment. Structures placed landward of the beach will serve as a defense of last resort when rising lake levels and/or severe storms temporarily wipe out natural beach defenses against erosion. During times of falling and low lake levels, wind-blown sand covers some low structures built against the upland slope. Only the sandy beach is visible. Minimal adverse impacts may also be expected where there is minimal longshore sediment transport and an erosion-resistant lakebed. Minimal impacts can be expected where the structure augments natural protection, such as a seawall built on a too-low, sloping bedrock shore.

The closer that a seawall or revetment is to the water, the greater the negative impacts on the protected property and on neighboring properties. Shore protection structures in the water or at the water's edge reflect wave energy, alter longshore currents, and may alter sediment transport. Storm waves can cause localized lakebed scour in front of, and at the ends of, the structures. Deepening of the water in front of a lake-edge seawall or revetment by localized scour or lakebed erosion may undermine the structure and cause it to collapse.

Construction of any shore protection structure that impedes the longshore transport of sediment should be avoided, or approached with extreme caution.

During periods of low water levels, shoreland should not be "reclaimed" by building revetments and seawalls near the receded water's edge to protect beaches, sand ridges, and swales that have emerged while lake levels were declining. Structures built in these locations interfere with the beneficial restoration of natural shore protective buffers and may be destroyed when high lake levels return and storms occur.

Impacts of breakwaters

A nearshore breakwater breaks waves and creates a zone of quiet water on the inshore, sheltered lee side of the structure where a change in habitat and animal communities is likely to occur. Longshore movements of fish may be impeded. This local change in nearshore conditions can contribute to a local degradation in water quality and cause longshore transport to deposit sediments in the sheltered waters. Breakwaters can deflect longshore sediment transport offshore into deep water where the material will not return to the nearshore and to beaches.

Designers shape breakwaters to maximize desired effects and reduce negative impacts. A breakwater may be located lakeward of the normal breaker zone, or the structure length may be made less than the distance between the structure and shore to avoid the creation of a shoreline spit that eventually reaches the breakwater and forms a "tombolo" that blocks longshore sediment transport between the structure and the shore.

Water safety, shoreline aesthetics, altered habitat, and cumulative impacts

Rip currents that are dangerous to swimmers can be formed adjacent to long groins or piers, where structures have altered nearshore bar formation, and within the water cells framed by breakwaters and pocket beaches.

As more shorelines become developed, armored, and exposed at low water levels, the massive appearance of many shore protection structures becomes a growing issue with neighbors and with regulators as the shore loses its natural look.

Shoreline and nearshore habitats on the Great Lakes are important. Shore protection structures may alter habitat for birds and other animals living in nearshore waters and on the beach. Shoreline waters are used by many fish and by organisms on which fish feed. The influence of shore protection structures on these nearshore habitats is poorly understood but could have significant effects on the Great Lakes fishery over long periods of time as such structures multiply.

As shoreline structures multiply along a section or reach of shoreline, cumulative impacts are of growing concern. Cumulative impacts are poorly understood and have had little investigation. The issue can appear in at least three ways: 1) impacts on the shoreline and nearshore from the addition of multiple shore protection structures, 2) a total impact greater than the sum of effects from individual structures, and 3) impacts from one or more structures multiplying over time and distance along a shore.

Private actions, public consequences

Private actions on private property can have public consequences. This is often the case for slope stabilization and shore protection on coastal property. Private actions may adversely affect the properties of neighbors and more distant residents along the coast. The adverse effects are progressive over time and distance. Some of these adverse effects may be undetected, occurring in the midst of shore-land changes caused by winds, water on the land, storm waves, and lake level changes. The public consequences of private shore protection actions become more significant as coastal investments increase, and beaches diminish.

Distant public and private actions far from any shore protection structure may also be responsible for the losses of beaches and protective nearshore bars. Beach sand and gravel from inland sources are lost or diminished by soil erosion control, construction of dams and breakwaters, harbor deepening (creating sediment traps) and the placement of dredged material containing clean sand and gravel in upland locations or offshore sites beyond the reach of the littoral system.

Working with Engineers and Contractors

Shore protection as a do-it-yourself project is often done as a series of short-term experiments in a vain and costly search for a long-term solution. Qualified and experienced professionals are necessary for finding long-term solutions. They can support the permitting process and help deal with public concerns and neighbors' concerns about a planned project. An investment in these services is the best way to achieve the desired performance, attain the desired life of a project, and reduce costs during the period of ownership.

steps of a shore protection project

- Selection of technical advisor or consultant
- Analysis and design by consultant (detailed below)
- Preparation and submittal of permit applications to regulatory agencies
- Design modifications (if needed) and permit approvals
- Solicitation for bids and selection of a contractor
- Construction
- Monitoring the shore protection at least annually and after major storms
- Repairing and replacing the shore protection as needed

working with a contractor

A typical shore protection contractor will do the following:

- Provide references of clients for whom similar work was done
- Submit a bid to construct the works and execute a construction contract
- Mobilize material and equipment on site
- Provide people to manage and carry out the construction
- Meet on a regular basis with the owner and engineer to review progress and resolve problems as they arise
- Demonstrate that the work is being performed in accordance with the specifications

If an anticipated project is to include slope stability and erosion control, and/or shore protection structures, select only qualified consultants who are experienced in slope stability, erosion control, and/or shore protection design. Such consultants are typically geotechnical or coastal engineers. They should also be registered and licensed to practice in the state or province where the work is to be done. Licensing requires proof of significant experience and indicates an expected high level of professional conduct.

A slope stabilization/shore protection project that goes beyondrevegetation and surface-water control generally follows the steps shown in the sidebar.

Nearly all of the property owner's decisions that affect the final cost will be made with the engineer before the structure is built. The decisions include: what slope stabilization option to accept, which structure option to choose, and whether or not to accept a set of plans. Bids need to be solicited from contractors and accepted or rejected. The decisions will affect initial cost, maintenance costs and the expected life of the protection system. During construction, the engineer can represent the owner in administration of the contract and monitoring work in progress. The engineer can do periodic post-construction monitoring of the slope and structure condition.

The contractors (and subcontractors) should be experienced in the work they are expected to do, whether

working with a designer

The following list indicates what a coastal property owner can reasonably expect from a competent experienced designer of shore protection structures:

- References of clients for whom similar work was done
- A stated specific life expectancy (design life) based on the owner's needs
- A statement of specific extreme combinations of storm water levels and storm wave conditions used in design, with a stated level of damage acceptable to the owner
- A statement of the percentage chance that excessive damage will occur over the expected period of ownership
- A design that addresses potential wave scour and lakebed erosion issues
- A plan to avoid or accommodate overtopping by storm waves in a way that minimizes damage
- Evidence of flank protection for both ends of the structure
- A design of a sound structure foundation to prevent structural settling and loss of soil landward of the structure
- Plans that include dimensions of the structure referenced to a water level measurement stated in feet or meters above or below a particular stated Great Lakes datum
- A written statement explaining how the design takes into account the possibility of creating adverse environmental effects on neighboring shore properties and identifies measures to be taken to minimize this potential
- A written statement of steps to be taken by the design professional and the contractor to ensure adequate quality of construction
- A written statement of the need for inspection and repair/replacement of damaged structure portions following major storm events
- A written statement of the regulatory issues that need to be addressed

Some of the items in the list apply to plans for nonstructural measures

selecting and planting vegetation, constructing for groundwater control and slope stabilization, or constructing waterfront works, such as armor-stone structures and seawalls. The contractor is responsible for taking the design prepared by the engineer and carrying out the project in conformance with the plans and specifications. A contractor can be expected to provide the services listed in the box on page 32.

The importance of obtaining a competent contractor to build to the engineer's plan cannot be overstated. Request names and contact previous customers of contractors being considered for a project: customers for whom similar work was done.

Do not assume that the contractor with the lowest bid should be awarded the construction contract. A low bid may reflect inexperience in construction of coastal works. If the construction quality is poor, the constructed or reconstructed project will require a high degree of maintenance (or replacement), resulting in long-term costs that may be higher than the overall costs of an adequate protection system. Coastal construction on the land/water boundary of the Great Lakes is a specialty.

THE ECONOMICS OF PROTECTING YOUR COASTAL INVESTMENT

The economics of protecting coastal property are important to people seeking long-term coastal property investments for a future retirement home, for profitable resale, or to pass along to children and grandchildren. Choices that prospective buyers of coastal property make affect the future fate and value of their investment. When buyers compete for more desirable properties (including less risky investments), property prices will be bid up. Buyers desire coastal buildings that are secure from the hazards of flooding and erosion.

There are at least two ways to recover property value lost to erosion. One way is to relocate a threatened house further from the lake. The other way is to construct shore protection.

Shoreline Property Features and Value

The physical characteristics of coastal property safe from flooding and erosion are well known. The effects of these characteristics on market value are less known. There is some information from studies of Great Lakes coastal real estate markets in Michigan, Ohio and Wisconsin. The information applies to informed buyers of property with erodible bluff and bank shores but not to uninformed buyers, nor to the less-common rocky shores, low-lying shores with flood hazards, and sandy shores with fine recreational beaches. Important attributes that have significant effects on coastal property value are included in the box below.

The best coastal properties for investment on Great Lakes erodible shores have deep lots with large setback distances between existing buildings and the edges of coastal slopes or ample spaces for new buildings with large setback distances.

property value influences

Coastal property features that influence property value include:

- Lakefront location
- Severity of a coastal erosion hazard
- The presence of shore protection
- Risk of flooding
- Spaciousness of the house and property
- Age of house
- Type of construction
- Neighborhood attributes
- Accessibility attributes: distance to shopping, workplace, entertainment, etc.
- Amenities: fireplaces, number of bathrooms, etc.

Lakefront location adds about 50 percent value to Great Lakes shore property compared with a similar house and lot at a nearby inland location. Property value decreases as shoreline erosion brings the edge of a coastal slope closer and closer to a building. This decrease in value is more noticeable and occurs earlier in the Great Lakes region than in Pacific, Atlantic and Gulf Coast regions of the United States. Property value losses accelerate as erosion proceeds and the time until a coastal building becomes uninhabitable dwindles. A house is given an extended lease on life (and greater value) when it is relocated landward to a new site. Such an increase in value may be greater than the costs of relocation.

A building that can be easily relocated is the best type of building to build or buy where erosion has taken away much of the remaining setback space and time before a building site is threatened with loss.

The presence of recognizable, high-quality shore protection adds value to coastal property. This fact is known from studies involving constructed shore protection and seems likely to be true for natural shore protection as well. Shore protection structures that have been designed to be effective and arrest erosion for 25 years will restore more property value than shore protection that is not designed and is likely to arrest erosion for only 10 years. As coastal property becomes much more valuable, larger investments are economically justified in pursuing the best options for protecting coastal investments.

From a community perspective, the added value of shore protection to the property owner may be offset by declining property values of inland and adjoining neighbors if the armor degrades an accessible recreational beach or creates adverse effects (increased erosion, disappearance of beach) on neighboring property. There are negative economic effects of armoring just as there are negative environmental effects.

In circumstances where coastal property owners want to work cooperatively to improve shore protection and are individually willing to contribute at least the cost that their participation imposes on the group, each owner is likely to realize higher net economic benefits than if he/she had acted alone.

Ordinances restricting how close buildings can be placed to the lakeward edge of a bluff or bank cannot be assumed sufficient to protect long-term coastal investments.

Discounting of property value for erosion hazard increases markedly as a house becomes visibly and obviously endangered. Similarly, the recovery of property value with relocation of a house or construction of a shore protection structure is greater when the action is taken at the time of danger rather than long before the danger becomes obvious. One problem with waiting to take action is that in many places erosion doesn't occur incrementally in small predictable losses but massively in large, unpredicted slump blocks. Another problem with waiting to act is that building movers may refuse to bring heavy equipment on site when erosion has proceeded to a stage where the danger is obvious to the property owner. Waiting too long to act is one of several reasons for houses falling over faces of Great Lakes bluffs.

Will Government Regulations Protect a Coastal Investment?

It is common for governments to adopt shoreland ordinances that limit how close buildings can be built to the edges of coastal bluffs and banks along the Great Lakes. In some places this coastal buffer of unbuildable land is called an environmental corridor, or an erosion hazard zone, or erosion hazard area. Such buffers have environmental benefits and contribute to the value of adjacent property.

The widths of coastal environmental corridors are picked for environmental reasons. The corridors also provide protection for buildings on the landward side of the corridors. However, such corridors may not be adequate for protection of coastal buildings. The selection of coastal erosion hazard areas is based on compromises with competing desires: a) a desire for consistency with earlier planning horizons, b) a desire to avoid creating "unbuildable" lots already platted, c) a desire to avoid litigating a "taking" of private property, and d) a desire to provide long-term safety for coastal buildings. Governments' incentives to avoid litigation tend to be stronger than incentives to provide safe distances between buildings and the dynamic boundary of the Great Lakes. It is common for governments to grant variances for coastal construction setback requirements.

A common situation where variances are considered and granted is an application for construction on land between lots where buildings exist that don't meet present minimum setback requirements. Shore erosion in front of neighboring older buildings has used up some of the distance and time until those buildings are threatened. A common variance method is averaging of the existing setback distances on either side of the applicant's property and using that average distance as the setback required on the applicant's lot.

Such setback variances fail to bring reduced risk of damage from erosion to new construction in developed areas where risk reduction may be most needed. Limiting setback variances to coastal properties with easily relocatable buildings is one way to lessen future risk of damage and loss from erosion.

limits of setback averaging

Setback averaging on eroding shores:

- Shortens the time until erosion poses a threat to the new building
- Perpetuates past, unwise building site decisions
- Allows the construction of new buildings at distances that are not adequate for the useful lives of the new structures

Costs of Shore Protection

It is tempting to choose shore protection structure bids based on initial costs without knowing the expected life of the structure and expected maintenance costs during that lifetime. The lifetime costs of a well-designed structure with a higher initial cost may be less than the lifetime costs of a poorly designed structure with a lower initial cost. Where coastal property values have been rising faster than construction costs, the cost of shore protection is becoming a smaller percentage of coastal investments. Some of the shore protection strategies mentioned in this booklet may be more effective, and less costly, if done cooperatively. A common group effort to construct shore protection structures can sometimes save between 20 to 40 percent compared with the costs of acting alone. An experienced professional can develop cost comparisons for property owners.

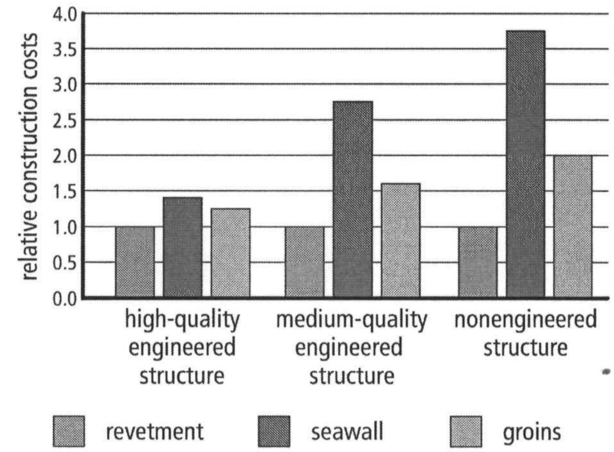
Initial costs

The graph shows the relative costs of three typical types of shore protection structures—revetment, seawall, and groin—for three different levels of design. The initial construction costs considered in this graph are labor and material costs. Preparation costs, such as site clearing, excavation, grading, splash aprons and drainage systems are not included here. Neither is the cost of periodically filling and refilling groins included.

Maintenance costs

Maintenance costs depend on past decisions and actions by a property owner—the design and construction quality, and the frequency of inspection and minor maintenance. Maintenance costs also depend on physical environmental factors (such as the frequency and severity of storms, range of lake levels) beyond the control of a property owner. Regular maintenance will maintain the performance and durability of the structure and lengthen its useful life.

Experienced contractors and consulting engineers have some idea of the relative magnitude of monitoring and maintenance costs to expect for particular types of structures in particular environments. For example, one suggested rule of thumb is that the average annual inspection, maintenance and repair cost for armor stone shore protection along the margins of the Great Lakes ranges from 2 to 5 percent of the initial construction cost for well-engineered structures. For an engineered, well-built structure, replacement may come in 20 years—a common design life. For a nonengineered structure, the useful life is difficult to estimate.



Relative Construction Costs of Shore Protection Structures

The cost to remove and dispose of old riprap may be 75 to 100 percent of the cost of placing new riprap. The cost to remove and dispose of old sheet pile may be 50 to 100 percent of the cost of installing new sheet pile. Extra costs may be incurred because of weather interruptions and delays, limited access to the site, costs of equipment mobilization and demobilization, extent of work required, and labor costs.

Risk Management

Risk exists whenever and wherever there is a variability of outcomes associated with an event or situation. Risk management can be applied to any situation in which there is risk. Many people with a long-term ownership or investment interest in coastal property face a risk of property damage or loss. The risk exists because

the risk managment process

- Specify problems and opportunities
- Identify and assess exposures
- Formulate alternative plans
- Evaluate potential effects
- Compare alternative plans
- Select and implement plan(s)
- Monitor

A Great Lakes beach during low water levels

the investment is in close proximity to powerful natural forces that are not adequately understood and are not controllable.

The following section briefly describes each of the steps of the risk management process applied to coastal erosion. Professional advice is needed in following this process.

Risk management is the patient practice of following a cycle of steps that will control one's exposure to losses.

Step 1: Specify Problems and Opportunities: The property owners need to identify objectives. Was the property purchased for the superior location and view? Was the property purchased as a long-term investment or as a short-term investment in order to turn a profit at resale? Be actively involved in stating problems and identifying opportunities. One common problem is a home (or other building) threatened by coastal erosion. One opportunity is to add amenities and value to the property when implementing some measure to reduce the erosion risk.

Step 2: Identify and Assess Exposures: The consultant will determine what property characteristics could prevent the property owners from meeting their property goals. The consultant will determine how susceptible the property is to erosion loss and how soon a building is likely to be threatened by structural instability from erosion. It seems reasonable and desirable to compare the erosion risk to buildings on coastal property with other long-accepted risks to buildings on all kinds of properties. The probabilities of such risks occurring can be compared, with the assistance of professionals.

Steps 3-5: Formulate Alternative Plans, Evaluate Potential Effects and Compare Alternative Plans: From a property owner's perspective, these steps can be lumped into one category. The consultant develops and analyzes the options available for minimizing the chances of erosion loss. The consultant determines which options will provide the most erosion protection with the fewest negative effects. The property owners should indicate how much money they are willing to spend to minimize this loss.

Step 6: Select and Implement Plan: The property owners choose a plan based on (a) costs, (b) levels of erosion reduction, and (c) effects on the owners' objectives. After the erosion control plan is selected, the consultant arranges for it to be put into practice.

Step 7: Monitor: Regular monitoring is an essential element in managing risk in coastal investments. This step begins as soon as the selected plan has been put into effect. The property owners take the greatest responsibility for the erosion risk management by inspecting (or contracting with the consultant to inspect) the property at regular intervals to look for any changes that might increase the likelihood of erosion loss. The consultant should develop a checklist of erosion warning signals. If the condition of the property has changed, prompt corrective action may be required.

Remember that coastal erosion risk management is an ongoing process. With the help of coastal professionals and proper usage of the risk management process, coastal property owners can meet their underlying objectives of secure property investment.

Accounting for Climate Change

The success of strategies for protecting coastal investments depends in part on the nature of climate changes during the period of property ownership. Will the effects of climate changes come soon? Will there be more, or fewer extreme precipitation events? Will lake levels be higher or lower than historic levels? Will storm events be more or less severe, more or less frequent?

Adaptation strategies for shore protection should be easier if climate change brings slow change, lower lake levels, fewer extreme precipitation events, and fewer extreme storm wave events. These strategies become more challenging if damaging storm waves riding in on high lake levels hammer the shore as they did in the early 1970s and mid-1980s, if more extreme precipitation events occur, or if effects of climate change come quickly.

The same Great Lakes beach shown on page 37 during high lake levels

levels. Armor-stone structures will experience more rapid disintegration if climate change brings to winters a greater frequency of freezing and thawing cycles.

There has been a lot of experience in dealing with high lake levels over the last half of the last century, but relatively little experience with low lake levels.

Most shore-side facilities on the Great Lakes were designed and sited for the climate conditions that existed at the time. It is a challenging task to adapt lakeside power plants, water intakes, pumping stations, sewage treatment plants, industrial plants, harbors and marinas to lake levels and storm conditions beyond the ranges for which they were designed. Adaptation is also a challenging task for owners of old homes on small lots and owners of large, new homes close to the lakes on the edges of eroding coastal slopes if climate change brings high water levels and greater or more frequent storm events.

Restoration of protective beaches, dunes and ridges will become easier if climate change brings low lake levels, but only where there are ample sand and gravel deposits near shore. There has been a loss of beach-building materials due to coastal armoring, soil loss control on basin lands and upland placement of clean dredged material. Restoration of coastal wetlands may become difficult if water levels drop below historic low levels.

Armoring will become more challenging if climate change brings more frequent or more intense storm wave events, or if lake levels return to, or exceed historic high

One approach to climate change is to base shore property development and protection decisions on the historical record of erosion (if known) with an allowance for future extreme lake levels and storms, beyond those of the historical record. A statistical study (like the one mentioned in "Future Climate Effects on Lake Levels") can be useful.

A second approach is an incremental adaptive approach that recognizes the short-term risk: water levels can change more than three feet (more than one meter) over several years. It is important to learn about the latest results from modeling of climate change and plausible water-level change scenarios, particularly with respect to the timing, magnitude and direction (higher or lower water levels) of the change. Climate change could bring occasional periods of high water levels, even if low water levels become common. It's also important to watch for predictions about changes in the intensity and frequency of storm and precipitation events. A risk assessment can then be made based upon the expected economic life of the coastal investment and the timing of expected climate changes.

SUMMARY

Owners of property along the edges of the Great Lakes have land with soil characteristics left by ancient glaciers and larger old lakes with much higher and lower water levels. There is a lot of variation in soil properties from lot to lot and from lake to lake. Shore property owners also have land with a wide range of natural shore and slope protection—in some places insufficient—making human intervention necessary.

Water on and in the land, waves, wind, and below-freezing air temperatures work in concert to alter coastal slopes, undermine and destroy built shore protection, flood beaches and low-lying land, or expose beaches and nearshore lakebed.

Lakefront location appears to add about 50 percent to the value of Great Lakes residential shore property compared with the value of similar property at a nearby inland location. A safe distance between a coastal home and the edge of its coastal slope property is of greater economic value than proximity to the shore or size of the home. A coastal house imperiled by erosion gains economic value and a new lease on life when relocated, or when slope and shore protection is constructed.

Many people who own coastal property face a risk of property damage or loss because their investment is in close proximity to erratic powerful natural forces. Risk management should be applied to coastal property ownership to minimize the adverse consequences of risk. The seven common steps of risk management are relevant to all sizes of coastal property from unbuilt lots to major developments. The most neglected element in coastal risk management is regular monitoring to detect changes that may increase the likelihood of loss.

Water and wind combine to rearrange the margins of the coastal lands around the Great Lakes.

The best responses to natural processes that threaten coastal buildings and other land structures are a mix of adaptation to the processes, restoration of natural shoreline defenses, and slowing erosion. These responses are challenging when climate change brings rapid change, high water levels and storm events of greater frequency or intensity and where the depth of coastal lots is marginal for relocation of existing buildings and selection of large setback distances for new buildings. These responses are easier when climate change brings slow change, low water levels and less frequent or less intense storms and where coastal lots are spacious.

Armoring the shore should always be a measure of last resort. Armoring is not a one-time action but requires constant monitoring and occasional repair or replacement. Armoring has impacts on neighboring properties—many of them negative impacts. Shore protection along the open coasts of the Great Lakes is no longer a "help yourself" situation in many places. Armoring and slope stabilization are complex activities that need the services of experienced engineers and contractors.

Climate change should be anticipated in making and safeguarding coastal property investments. There are several possible approaches. One is a conservative approach that allows for greater extremes in lake level, ice conditions, precipitation and storm intensity and frequency than those of historical record. Another approach is an incremental adaptive approach that responds to climate changes as they happen.

The practice of building close to the edges of erosive coastal slopes should be discouraged because it minimizes a natural buffer distance that is needed to keep risk management options open and to accommodate climate changes that are more extreme than the climate conditions encountered during the historical period of coastal settlement.

WHERE TO GO FOR MORE INFORMATION

Most of these sources have Web sites.

Climate change, or its effects on Great Lakes lake levels

Adaptation and Impacts Research Group, Atmospheric Environment Service, Environment Canada

Canadian Climate Impacts and Adaptation Research Network

Climate Prediction Center, NOAA National Weather Service,

Great Lakes Environmental Research Laboratory, NOAA

Intergovernmental Panel on Climate Change (IPCC), United Nations Environmental Program

National Academy Press Publications Catalog, National Academy of Sciences

Pew Center on Global Climate Change

U.S. Environmental Protection Agency

U.S. Global Change Research Program

World Meteorological Organization (WMO)

Great Lakes information

Great Lakes Hydraulics and Hydrology Office, Detroit District, U.S. Army Corps of Engineers

Great Lakes Information Management Resource (GLIMR), Canada Centre for Inland Waters

Great Lakes Information Network (GLIN), Great Lakes Commission

Great Lakes water levels

Canadian Hydrographic Service, Department of Fisheries and Oceans, Canada (present and forecasted levels)

Center for Operational Oceanographic Products and Services, National Ocean Service, NOAA

Great Lakes Environmental Research Laboratory, NOAA

Great Lakes Hydraulics and Hydrology Office, Detroit District, U.S. Army Corps of Engineers (present and forecasted levels)

Marine Environmental Data Service, Department of Fisheries and Oceans, Canada

Great Lakes storm surges

Conservation Authorities and Water Management Branch, Ontario Ministry of Natural Resources

Great Lakes Environmental Research Laboratory, NOAA (storm surge planning program software)

Great Lakes Hydraulics and Hydrology Office, Detroit District, U.S. Army Corps of Engineers (storm surge statistics)

Great Lakes wave conditions

National Data Buoy Center, National Weather Service, NOAA (present and recent wave and wind conditions)

Wave Information Studies of US Coastlines (WIS reports) Publications. Coastal and Hydraulics Laboratory, Research and Development Center, U.S. Army Corps of Engineers (wave statistics)

Ice on the shore

Ashton G. D. *River and Lake Ice Engineering*. Water Resources Publications

Assel R. *Great Lakes Ice Atlas*, Great Lakes Environmental Research Laboratory, NOAA

Cold Regions Research and Engineering Laboratory, U.S. Army Corps of Engineers

Engineering Manual, Publications (1986) *Ice Engineering*. U.S. Army Corps of Engineers

Relocating buildings

International Association of Structural Movers

Midstates Housemovers Association

Minnesota Building Movers Association

Ontario Structural Movers Association

Strategies of adaptation, restoration, moderation and armoring in shore protection

Coastal Engineering Manual (May 2002) Part V, Chapter 3. Shore Protection Projects. Coastal and Hydraulics Laboratory, Engineer Research and Development Center, Waterways Experiment Station, U.S. Army Corps of Engineers. CD-ROM version from Veri-Tech, Inc., expected in fall 2003.

Ontario Ministry of Natural Resources (2001) *Great Lakes-St. Lawrence River System and large inland lakes, Technical guides for flooding, erosion and dynamic beaches in support of natural hazards policies 3.1 of the provincial policy statement*. CD-ROM. Watershed Science Centre Trent University, Peterborough, Ontario.

Ontario Ministry of Natural Resources (2001) *Understanding Natural Hazards*. 40-page booklet.

Pope J. (1997) *Responding to Coastal Erosion and Flooding Damages*. Journal of Coastal Research, vol. 13, No. 3, pages 704-710.

Nourishing beaches

North Carolina Shore and Beach Preservation Association

San Diego Association of Governments (SANDAG)

Shore and Beach. Journal of the American Shore and Beach Preservation Association

Vegetating the shore

Massachusetts Wetlands Restoration Program

Washington State Department of Ecology Shorelands and Coastal Zone Management Program, publication titled *Controlling Erosion Using Vegetation*.

Wisconsin Department of Natural Resources

Rehabilitation of wetlands

Association of State Wetland Managers, Inc.

Environmental Concern, Inc.

Society for Ecological Restoration

Society of Wetland Scientists

Wilcox, D.A., Whillans, T.H. (1999) *Techniques for Restoration of Disturbed Coastal Wetlands of the Great Lakes*, Great Lakes Science Center, U.S. Geological Survey, Ann Arbor, Michigan and Environmental and Resource Studies, Trent University, Peterborough, Ontario, Canada

Soils in coastal properties

Well drilling contractors' drilling records can typically be obtained from a county health department, county registrar of deeds, highway department, or from the contractors who drilled the wells.

Slope stabilization

Abrahamson, L. W., et al. (2002) *Slope stability and stabilization methods*. 2nd edition, John Wiley and Sons, NY, 712 pages.

Gray D. H. and Sotir R. B. (1996) *Biotechnical and Soil Bioengineering Slope Stabilization*. John Wiley and Sons, Inc., New York. 375 pages.

International Consortium on Landslides, Landslide Section, Japan

International Erosion Control Association

Construction of beach ridges and dunes

Caulk A.D., Gannon J.E., Shaw J.R, and Hartig J.H. (2000) *Best Management Practices for Soft Engineering of Shorelines*. Greater Detroit American Heritage River Initiative and Partners, Detroit, Michigan.

Environmental Protection Agency and the Queensland Parks and Wildlife Service. Queensland Wildlife Parks Association

Northern Prairie Wildlife Research Center

Shore and Beach. Journal of the American Shore and Beach Preservation Association

Shore Protection Manual. 1984. 4th ed., Vols. I & II, Coastal and Hydraulics Laboratory, Research and Development Center, U.S. Army Corps of Engineers.

Managing water on the land

Forrester, K. (2001) *Subsurface Drainage for Slope Stabilization*. American Society of Civil Engineers Press.

Cedergren, H.R. (1989) *Seepage, Drainage and Flow Nets*. (1989) 3rd Edition. John Wiley and Sons, New York.

Washington State Department of Ecology Shorelands and Coastal Zone Management Program, Controlling Erosion Using Vegetation

Armored shore protection structures

Coastal Engineering Manual (February 2003) Part VI, Chapter 3. Shore Protection Projects. Coastal and Hydraulics Laboratory, Engineer Research and Development Center, Waterways Experiment Station, U.S. Army Corps of Engineers. CD-ROM version from Veri-Tech, Inc., expected in fall 2003.

Construction Industry Research and Information Association (1986) *Seawalls: Survey of performance and design practice*. Technical Note 125. London, UK.

McConnell, K. (1998) *Revetment systems against wave attack: A design manual*. Thomas Telford Ltd., London, UK.

Pilarczyk, K and Zeidler, R. (1996) *Offshore breakwaters and shore evolution control*. A.A. Balkema, Rotterdam, The Netherlands.

Pilarczyk, K. (1998) *Dikes and revetments: Design, maintenance and safety assessment*. A.A. Balkema, Rotterdam, The Netherlands.

Thorn, R.B. and Roberts, A. (1981) *Sea defence and coast protection works: A guide to design*. Thomas Telford Ltd., London, UK.

Watershed Science Centre and Ontario Ministry of Natural Resources (2001) *Great Lakes-St. Lawrence River System and large inland lakes, Technical guides for flooding, erosion and dynamic beaches, etc.* CD-ROM.

Whitehouse, R. (1998) *Scour at marine structures: A manual for practical applications*. Thomas Telford Ltd., London, UK.

Environmental impacts of shore protection structures

Dean R.G. (1986) *Coastal armoring: Effects, principles and mitigation*. *Proceedings of the 20th Coastal Engineering Conference*, Taipei, Formosa. Volume 3. American Society of Civil Engineers.

Kraus N. C. and Pilkey O.H. (1988) *Journal of Coastal Research*. Special issue No. 4.

Shore and Beach. Journal of the American Shore and Beach Preservation Association

Kraus N.C. and MacDougal W.G. (1996) *The effects of seawalls on the beach: Part I. An updated literature review.* Journal of Coastal Research, No. 12. p. 619-701.

Proceedings, Coastal engineering conferences. American Society of Civil Engineers

Finding qualified consultants

For the Qualification Based Selection (QBS) procedure for selecting a consultant, contact the

Wisconsin Association of Consulting Engineers, Madison, Wisconsin. A free QBS manual can be read or downloaded from the Internet. Do a Web search for "ACECWI"

Consulting engineers in Ontario. Contact the Consulting Engineers of Ontario (Phone: 416-620-1400) to learn of firms with capabilities in coastal engineering. Check with Professional Engineers Ontario to determine if particular consultants are members in good standing.

Consulting engineers and geologists in the United States. In the Yellow Pages of phone books, look for registered professional engineers under: marine engineers, consulting engineers, civil engineers, environmental engineers, or coastal engineers. To find registered professional geologists or geoscientists look in the Yellow Pages. Contact state and provincial associations of these professionals. One such association is the American Institute of Professional Geologists (AIPG). The association has a web page with links to various state sections of the association.

Risk management

Bernstein P. L. (1996) *Against the Gods; the Remarkable Story of Risk.* John Wiley and Sons, Inc., New York.

Coastal Engineering Manual (February 2003) Part V, Chapter 2. Planning and Design Processes. Coastal and Hydraulics Laboratory, Engineer Research and Development Center, Waterways Experiment Station, U.S. Army Corps of Engineers. CD-ROM version from Veri-Tech, Inc., expected in fall 2003.

Heinz, H. J. III Center for Science, Economics and the Environment (2000) *The hidden costs of coastal hazards: Implications for risk assessment and mitigation.* Island Press, Washington D.C.

Institute for Business and Home Safety (IBHS). Boston, Massachusetts

Institute for Catastrophic Loss Reduction (ICLR). University of Western Ontario, London, Ontario, Canada

Jones C. P. and Rogers, S. M. Jr. (2001) *Establishing standards for building setbacks: incorporation of erosion rate variability.* Proceedings, Solutions to Coastal Disasters Conference. American Society of Civil Engineers.

Risk Analysis and Management for Projects. Institute of Civil Engineers and Institute of Actuaries. London, U.K.

Rogers, S. M. Jr. and Jones C. P. (2002) *Selecting erosion setbacks for balanced multi-hazard risk.* Proceedings, Solutions to Coastal Disasters Conference. American Society of Civil Engineers.

Natural Hazards Center, University of Colorado. Publications

Economics of shore protection

Kriesel W., Randall A., and Lichtkoppler F. (1993) *Estimating the benefits of shore erosion protection in Ohio's Lake Erie housing market.* Water Resources Research. Vol. 29, No. 4, pages 795-801.

Heinz, H. J. III Center for Science, Economics and the Environment (2000) *The hidden costs of coastal hazards: Implications for risk assessment and mitigation.* Island Press, Washington D.C.

AGENCIES THAT REGULATE GREAT LAKES SHORELANDS

ILLINOIS

Illinois Department of Natural Resources
Office of Water Resources
James R. Thompson Center
100 W. Randolph Street, Suite 5-500A
Chicago, Illinois 60601

INDIANA

Information on shore protection
Lake Michigan Specialist
Indiana Department of Natural Resources
Division of Water
100 West Water Street
Michigan City, Indiana 46360
Phone 219-874-8316

Indiana Department of Natural Resources
Public Education and Outreach Section (information)
Division of Water (regulation)
402 W Washington Street, Room W264
Indianapolis, Indiana 46204
Phone 317-232-4160 or 1-877-928-3755

Indiana Department of Environmental Management (regulation)
504 N. Broadway, Suite 418
Gary, Indiana 46402
Phone: 219-881-6712

Environmental Manager
Indiana Department of Environmental Management (regulation)
100 North Senate Avenue
P.O. Box 6015
Indianapolis, Indiana 46206
Phone. 317-232-8603 or 1-800-451-6027

Supervisor Residential Sewage Disposal (regulation)
Sanitary Engineering
Indiana State Department of Health
2 North Meridian Street, 5-E
Indianapolis, Indiana 46204
Phone: 317-233-7177

MICHIGAN

Michigan Department of Environmental Quality
Geological and Land Management Division
P.O. Box 30458
Lansing, Michigan 48909-7958
Phone 517-373-1170

Permit applications should be obtained from the web site or from:
Michigan Department of Environmental Quality
Geological and Land Management Division
Permit Consolidation Unit
PO Box 30204
Lansing, Michigan 48909-7704

MINNESOTA

Minnesota Department of Natural Resources
Division of Water
DNR Building, 3rd Floor
500 Lafayette Road
St. Paul, Minnesota 55155
Phone: 651-296-4800

NEW YORK

New York State Department of Environmental Conservation
Bureau of Flood Protection
625 Broadway
Albany, New York 12233-3507
Phone: 518-402-8151

OHIO

coastal consistency, shore structure permits, coastal erosion area permits, submerged land leases, site visits
Ohio Department of Natural Resources
Office of Coastal Management
P.O. Box 373
Sandusky, Ohio 44871-0373
Phone: 419-626-7980
TOLL FREE: 888-644-6267

information on coastal erosion areas, Lake Erie geology and geologic processes, and site visits
Ohio Department of Natural Resources
Division of Geological Survey
Lake Erie Geology Group
1634 Sycamore Line
Sandusky, Ohio 44870-4132
Phone: 419-626-4296
TOLL FREE: 888-644-6267

water quality certification
Ohio Environmental Protection Agency
Division of Surface Water – 401/Wetlands Unit
P.O. Box 1049
Columbus, Ohio 43216-1049
Phone: 614-644-2001

PENNSYLVANIA

Pennsylvania Department of Environmental Protection
Bureau of Watershed Conservation
Watershed Support Division
Coastal Zone Management Program
Rachael Carson State Office Building
P.O. Box 2063, 400 Market Street
Harrisburg, Pennsylvania 17105-2063
Phone: 717-772-4785

Pennsylvania Department of Environmental Protection
Office for River Basin Cooperation
Coastal Zone Management Program
Rachael Carson State Office Building
P.O. Box 2063, 400 Market Street
Harrisburg, Pennsylvania 17105-2063
Phone: 717-772-4785

WISCONSIN

Wisconsin Department of Natural Resources
Bureau of Watershed Management
P.O. Box 7921
Madison, Wisconsin 53707
Phone: 608-267-7694

U.S. FEDERAL AGENCIES

Information on Great Lakes water levels and general information on their shoreline impacts:
U.S. Army Corps of Engineers, Buffalo District
1776 Niagara Street
Buffalo, New York 14207
Phone: 716-879-4104

U.S. Army Corps of Engineers, Chicago District
111 North Canal Street
Chicago, Illinois 60606-7206
Phone: 312-353-6400

U.S. Army Corps of Engineers, Detroit District
477 Michigan Avenue
Detroit, Michigan 48226
Phone: 313-226-6440

U.S. Army Corps of Engineers,
Great Lakes Regional Office
111 North Canal Street, Suite 1200
Chicago, Illinois 60606
Phone: 312-353-4333

ONTARIO

The starting place is the local Conservation Authority. They assist individual landowners with technical assistance and/or provide a list of qualified people who may help. The Conservation Authority does the pre-screening to determine whether or not they can handle the permitting issues themselves or whether to defer to the provincial and federal agencies. See the Conservation Ontario Web site for a list of the 36 Ontario Conservation Authorities, their addresses and Internet Web sites.

Ontario Ministry of the Environment
Water Policy Branch
40 St. Clair Avenue West, 12th and 14th Floors
Toronto, Ontario M4V 1M2
Phone: 416-314-3923

Ontario Ministry of Natural Resources
Peterborough Regional Office, 4th Floor
300 Water Street
P.O. Box 7000
Peterborough, Ontario K9J 8M5
Phone: 705-755-2500

Canadian Federal Agencies

Fisheries and Oceans Canada handles concerns about fisheries habitat impacts, The Canadian Coast Guard ensures that navigation is unimpaired, INAC is involved where First Nations lands may be impacted.

Canadian Coast Guard
201 North Front Street
Suite 703
Sarnia, Ontario N7T 8B1
Phone: 519-383-1865

Department of Fisheries and Oceans
Canadian Hydrographic Service
867 Lakeshore Road
P.O. Box 5050
Burlington, Ontario L7R 4A6
Phone: 905-336-4844 (water levels)
905-639-0188 (fisheries habitat)

Indian and Northern Affairs Canada (INAC) -
Ontario Region
5th Floor, 25 St. Clair Avenue East
Toronto, Ontario M4T 1M2
Phone: 416-973-6234

GLOSSARY OF COASTAL ENGINEERING TERMS

A more complete glossary can be found at the Publications web page of the Coastal Hydraulics Laboratory, U.S. Army Corps of Engineers under the Coastal Engineering Manual (CEM). Many of the following definitions come from or are modified from this source.

ACCRETION (of a beach) – Buildup of a beach by waterborne and/or airborne material, usually sand, gravel and larger stones.

ALONGSHORE (LONGSHORE) – Parallel to and near the shoreline.

AQUIFER – Soil layers through which water readily flows.

ARMOR STONE (ARMOR LAYER) – A number of relatively large quarrystone or concrete pieces that form primary wave protection on the outer surfaces of shore protection structures.

ARMORED SHORE – A shore with natural or constructed shore protection.

BEACH NOURISHMENT – The process of replenishing a beach with material (usually sand) obtained from another location.

BACKSHORE (BACKBEACH) – That zone of the shore or beach lying between the foreshore and the coastline comprising the BERM or BERMS and acted upon by waves only during severe storms, especially when combined with exceptionally high water.

BANK – A slope with relatively simple soil structure (and simple erosional processes) rising from the backshore of a beach with an elevation of 20 feet (6 meters) or less above the backshore elevation.

BAR – A submerged or emerged embankment of sand, gravel, or other unconsolidated material formed on the lakebed in shallow water by waves and currents.

BATHYMETRY – The measurement of depths of water in oceans, seas, and lakes; also information derived from such measurements.

BAY – An extension of a lake or ocean into a recess in the shore.

BEACH – The zone of unconsolidated material (usually sand, gravel, or larger stones called "shingle") that extends landward from the low water line to the place where there is marked change in material, or to the line of permanent vegetation (usually the effective limit of storm waves). A beach includes FORESHORE and BACKSHORE.

BEACH EROSION – The carrying away of beach materials by wave action, currents, or wind.

BEACH FACE (FORESHORE) – The section of the beach normally exposed to the action of the wave uprush.

BEACH FILL – Material placed on a beach to re-nourish eroding shores.

BEACH MATERIAL – Granular sediments (sand, stones) moved by the water and wind to the shore.

BEACH RIDGE – A nearly continuous mound of beach material that has been shaped by wind and waves. Ridges may occur singly or in multiple, approximately parallel forms.

BEACH WIDTH – The horizontal dimension of the beach measured perpendicular to the shoreline, from the still water level to the landward limit of the beach.

BEDROCK – The solid rock underlying soil and sediment, appearing at the surface where these materials are absent.

BERM – A nearly horizontal plateau on a beach face or backshore, formed by waves and wind.

BLUFF – A slope with relatively complex soil structure or complex erosional processes, rising from the backshore of a beach with a crest elevation of 20 feet (6 meters) or more above the backshore elevation. Bluffs are sometimes defined as high, steep banks or cliffs.

BLUFF RECESSION – The retreat of a bluff due to erosion.

BOULDER – A rounded rock more than 10 inches (25 centimeters) in diameter.

BREAKER – A wave breaking on a shore, over a reef, etc. Breakers may be classified into four types:

COLLAPSING – Breaking over the lower half of the wave.

PLUNGING – The crest curls over an air pocket and breaking usually occurs with a crash of the crest into the preceding wave trough.

SPILLING – Bubbles and turbulent water spill down front face of wave. The upper 25 percent of the front face may become vertical before breaking. Breaking generally occurs over quite a horizontal distance.

SURGING – The wave peaks up, and slides up the beach face with little or no bubble formation.

BREAKER ZONE – The area within which waves approaching the coast begin to break; typically landward of 16-33 feet (5-10 meters) water depths.

BREAKWATER – A structure protecting a shore area, or water area, from waves.

BULKHEAD – A structure or partition to retain or prevent sliding of the land. A secondary purpose is to protect the upland against damage from wave action.

CHART DATUM – A plane or level to which water depth soundings, land and structure elevations are referenced. Also known as LOW WATER DATUM in the Great Lakes.

COAST – A strip of land of indefinite width (may be several kilometers) that extends from the shoreline inland to the first major change in terrain features. The land regarded as near the shoreline.

COASTAL PROCESSES – Natural forces and processes that affect the shore and the nearshore lakebed.

COASTLINE – The boundary between coastal upland and the shore.

COBBLE (COBBLESTONE) – Loose stone, larger than gravel: approximately three to more than 10 inches (about six to more than 25 centimeters) in diameter.

COHESIVE SEDIMENT – Sediment with significant amounts of clay, having properties that cause the materials to bind together.

CREEP – Very slow, continuous down slope movement of soil or debris.

CREST – The highest point on a wave, beach face, berm, ridge, hill or shore structure.

CRITICAL ZONE – The soil mass within a slope where potential failure surfaces exist and where landslides may occur.

CURRENT -- A flow of water. This flow may be persistent (as in a stream) or temporary (as a wind driven current).

CURRENT, COASTAL – One of the offshore currents flowing generally parallel to the shoreline in the deeper water lakeward of the surf zone; may be caused by seiche, winds, or re-distribution of water mass.

CURRENT, LONGSHORE – The littoral current in the breaker zone moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.

DATUM (DATUM PLANE) – Any line or surface used as a reference for elevations.

DEEP-WATER – Water so deep that surface waves are little affected by the lakebed. Generally, water deeper than one-half the surface wavelength is considered deep water.

DOWNDRIFT – The direction of predominant movement of littoral materials.

DOWNCUTTING – Erosion of the lakebed.

DUNES – Ridges or mounds of loose, wind-blown material, usually sand.

DURATION – In wave forecasting, the length of time the wind blows in nearly the same direction over the FETCH.

EDGE WAVE – A solitary wave, or train of waves moving along the shore with crests roughly perpendicular to the shore. Its height is greatest at the shore and diminishes rapidly lakeward with negligible height one wave length from shore.

ELEVATION – The vertical distance of a surface from a DATUM.

ENVIRONMENTAL CORRIDOR – A strip of land with boundaries defined by government that is intended to protect natural resources, habitat, and space for recreational activities.

EROSION – The wearing away of land or a lakebed by the action of natural forces. On a beach, the carrying away of beach material by wave action, currents, or by wind.

EXPOSURE – Something of value that could be damaged or destroyed by a loss. It can be tangible (building, land, income) or intangible (access, enjoyment).

FACTOR OF SAFETY (SAFETY FACTOR) – The ratio of the strength of material (such as a soil mass) to the stress placed upon the material. A value of 1.0 represents a balance of strength and stress. Values greater than 1.0 indicate strength greater than stress.

FETCH – The area over which waves and wind setup (or surge) are generated by a wind having a fairly constant speed and direction.

FETCH DISTANCE (FETCH LENGTH) – The horizontal distance (in the direction of the wind) over which a wind generates waves, wind setup (or surge).

FOREDUNE – The front dune immediately behind the backshore.

FORESHORE – The part of the shore between the crest of the lakeward berm (or upper limit of wave uprush) and the low water line.

GABION – A wire mesh basket containing stone or crushed rock, designed to protect a slope from erosion by waves or currents. Sometimes used as a backing or foundation for shore protection structures.

GLACIAL TILL – Soils laid down by glaciers: consists of mixtures of silt, sand, clay and stones.

GRAVEL – small, loose stone; approximately 0.08 -3.0 inches (2-76 millimeters) in diameter.

GROIN – A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

GROUND WATER – Subsurface water occupying the zone of saturation. In a strict sense, the term is applied only to water below the WATER TABLE.

GULLY – A miniature valley worn in the earth by running water through which water usually runs only after rain events.

HAZARD – Any condition that increases the likely frequency or severity of a loss.

HEADLAND – An erosion-resistant promontory (or projection of land) extending into the lake.

HIGH WATER PERIOD – Years when lake levels are much greater than average.

ICE JAMS – Large accumulations of stationary ice that restrict water flow, flooding low-lying land along channels and rivers

ICE RIDGES – Linear piles of ice, grounded on the lakebed at locations where waves break, such as offshore bars.

ICE RUNS – Flowing ice in a river.

ICE SHOVE (ICE PUSH) – Ice sheets moved by wind and currents that come into contact with the shoreline and are shoved up the shore away from the lake.

ICEFOOT – An ice mass formed at the shoreline by waves that drive slush ice to shore.

IMPERMEABLE GROIN – A groin through which sand cannot pass.

INSHORE (ZONE) – In beach terminology, the zone of variable width extending from the low water line through the breaker zone.

JET STREAM – A long, narrow, meandering current of air high in the atmosphere that blows at high speed (often more than 200 miles per hour) from west to east.

JETTY – A structure extending into the lake to protect a harbor entrance from shoaling with littoral material.

LAG DEPOSIT – Stones, boulders in a glacial till lakebed that are left behind after the fine till materials have softened and washed away.

LAKE BOTTOM (LAKEBED) – The ground or bed under the lake.

LAKEBED ARMORING – The use of cobble stones to protect a lake bed from erosion by waves.

LANDSLIDE – The rapid downward movement of a mass of rock, soil or other material on a slope that is caused by the force of gravity.

LITTORAL – Pertaining to the shore of a lake or sea.

LITTORAL MATERIAL – Sand and stones moved by waves and currents near the shore.

LITTORAL TRANSPORT (LITTORAL DRIFT) – The movement of littoral material by waves and currents. Includes movement parallel (longshore transport) and perpendicular (on-offshore transport) to the shore.

LITTORAL ZONE – In beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the breaker zone.

LONGSHORE (ALONGSHORE) – Roughly parallel to and near the shoreline.

NEARSHORE – A zone extending seaward from the shoreline well beyond the breaker zone; typically to about 66 feet (20 meters) water depth.

NEARSHORE ICE COMPLEX – The varied ice cover features in a mass of ice anchored to shore.

OVERTOPPING – The passing of water over the top of a beach berm, dike, or other shore protection structure as a result of wave runup or surge action.

PENINSULA – An elongated body of land nearly surrounded by water and connected to a larger body of land.

PERCHED GROUNDWATER – Groundwater in a saturated soil zone above and separated from the main water table by unsaturated soil or rock.

PERCHED GROUNDWATER TABLE – The upper surface of a body of perched groundwater.

PERMEABILITY – The ability of water to flow through soil, crushed rock or other material.

PERMEABLE GROIN – A groin with openings large enough to permit passage of appreciable quantities of beach materials.

PIER – A structure extending out into the water from the shore, to serve as a landing place, recreational facility, etc., rather than to afford coastal protection. In the Great Lakes, a term sometimes applied to jetties.

PILE – A long, heavy section of timber, concrete or metal driven or jetted into the earth or lakebed to serve as a support or to provide protection.

POCKET BEACH – A beach (usually small) between two littoral barriers.

POINT – The outer end of any land area protruding into the water, less prominent than a peninsula.

POROSITY – The percentage of the total volume of a soil, or stones, occupied by air or water, but not by solid particles.

POTENTIOMETRIC WATER SURFACE (PIEZOMETRIC WATER SURFACE) – The level to which water will rise in avertical hole drilled into a water-bearing, water-transporting soil aquifer layer where water flow is confined to the aquifer layer because of higher flow resistance in soils above and below the aquifer layer; soils with lower permeability (lower hydraulic conductivity).

PROBABILITY – The chance that a certain event will occur, or be exceeded. Usually expressed as "p" with a value between 0 and 1.0.

QUARRY (QUARRYSTONE) – Any stone processed from a quarry.

REACH – A section of coastline that has characteristics in common.

RECESSION – The landward movement of the shoreline, beach, or lakeward edge of bank or bluff.

REEF – One or more stable lakebed forms of bedrock, loose rock or sand that rise above the surrounding lakebed.

REVETMENT – A structure of stone, concrete, etc., built to protect a shore against erosion by wave action or currents. Often used to refer to shore protection structures with sloping lakeward faces.

RIP CURRENT – A strong surface current flowing lakeward from the shore. It is the return movement of water piled up on the shore by incoming waves and wind.

RIPRAP – Protective layers of stone, randomly placed to prevent erosion, scour, or sloughing of a slope. Also used as a term to identify the stone used.

RISK – The possibility of negative outcomes or a loss.

RUBBLE-MOUND STRUCTURE – A mound of random-shaped and random-placed stones protected with a cover layer of selected stones or specially shaped concrete armor units.

SAND – Rock grains, most commonly quartz; that are 0.0025 – 0.19 inches (0.0625 – 4.76 mm) in diameter.

SCOUR – Removal of underwater material by waves and currents, especially at the base or toe of a shore structure.

SEAWALL – A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action.

SEDIMENT – Loose fragments of rocks, minerals, or organic material transported by air, wind, ice and water, and deposited. Also materials that precipitate from overlying water or chemically form in place. Includes all of the loose, unconsolidated material on a lakebed.

SEEP – A place where water in the ground oozes slowly to the ground surface.

SEICHE – An oscillation of the water mass in a lake that continues after the originating force has stopped. In the Great Lakes, such oscillations almost always have atmospheric causes. In other regions, seismic forces may be contributing causes.

SETBACK (SETBACK DISTANCE) – A selected (or required) space between a building (or other structure) and a boundary.

SHALLOW WATER – Water of such a depth that surface waves are noticeably affected by the lakebed. In terms of wave shoaling, it is water of depths less than one-half the wavelength.

SHEET EROSION – The removal of a thin layer of soil by wind or water.

SHEETPILE – Planks or sheets of construction material designed to be driven into the ground or lakebed so that the edges of each pile interlock with the edges of adjoining piles.

SHOAL (noun) – A detached elevation of the lakebed, comprised of any material except rock, which may endanger surface navigation.

SHOAL (verb) – (1) To become shallow gradually. (2) To cause to become shallow. (3) To proceed from a greater to a lesser depth of water.

SHORE – The narrow strip of land in immediate contact with the lake, including the zone between high and low water lines. A shore of unconsolidated material is usually called a BEACH.

SHORELINE – The intersection of a lake with the shore or beach.

SILT – Loose rock particles: smaller than sand particles and larger than clay particles.

SLOPE – The degree of surface inclination above a horizontal reference surface. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating 1 unit vertical rise in 25 units of horizontal distance; or in a decimal fraction (0.04); degrees (2° 18'); or percent (4 percent).

SLUMP – The movement of a soil mass downward along a curved failure surface; with the lower portion of the mass moving outward. A particular form of a slide, sloughing, or mass wasting from erosion.

SOIL - A layer of weathered, unattached particles containing organic matter and capable of supporting plant growth.

SPIT – A small point of land or a narrow shoal projecting into a body of water from the shore.

SQUALL LINE – A line of strong wind areas advancing ahead of a weather system along a boundary between air masses at much different temperatures.

STORM SURGE (WIND SETUP, STORM RISE) – A rise above normal water level on the open coast due to wind stress on the water surface over a long distance (fetch).

SWALE – The depressed area between two beach ridges.

SWASH ZONE – The area of wave action on a beach face from the lower limit of wave run-down to the upper limit of wave run-up.

TERRACE – A horizontal or nearly horizontal natural or artificial land surface feature interrupting a slope.

TOE – The lowest part of a structure forming the transition to the lakebed, or the lowest part of a slope forming a transition to a beach or terrace.

TOMBOLO – A bar or spit that connects or "ties" an island to the mainland or to another island.

TROUGH – A depression in the lakebed between bars – often created by breaking waves.

UNDERTOW – A periodic current beneath the water surface that flows lakeward when breaking waves are present, caused by the backwash of waves flowing down the beach face.

UPRUSH – The movement of water from a wave up a beach, or shore protection structure.

UPDRIFT – The direction opposite to the most common direction of littoral transport (or drift).

UPLAND – Land that is above the reach of waves and landward of the beach.

WATER DEPTH – The vertical distance between the lakebed and a water level, usually a still water level.

WATER LEVEL – The elevation of a still water surface relative to a datum.

WATER TABLE (GROUND WATER LEVEL) – The upper limit of the ground that is saturated with water.

WATER WAVE – A moving ridge, deformation, or undulation of the water surface.

WAVE BREAKING – The breakdown of a wave profile with a reduction in wave energy and wave height due to an unstable wave shape.

WAVE CLIMATE – The seasonal and annual distribution of wave heights, periods, and directions at a particular location.

WAVE CREST – (1) The highest part of a wave. (2) That part of the wave above still-water level.

WAVE DIRECTION – The direction from which a wave approaches.

WAVE HEIGHT – The vertical distance between a crest and adjoining trough.

WAVE LENGTH – The horizontal distance between two adjacent, successive wave crests.

WAVE REFLECTION – The process by which wave power and wave energy is returned lakeward.

WAVE PERIOD – The time for a wave crest to travel a distance of one WAVE LENGTH.

WAVE RUNUP (SWASH) – The rush of water up a structure or beach following the breaking of a wave; measured as the vertical height above still-water level to which the rush of water reaches.

WAVE TROUGH – The lowest water surface between two adjoining wave crests.

WETLAND – Land whose saturation with water is the dominant factor in determining the nature of soil development and the types of plant and animal communities that live in the soil and on the land.

WIND, DURATION – The length of time that the wind maintains roughly the same speed and direction.

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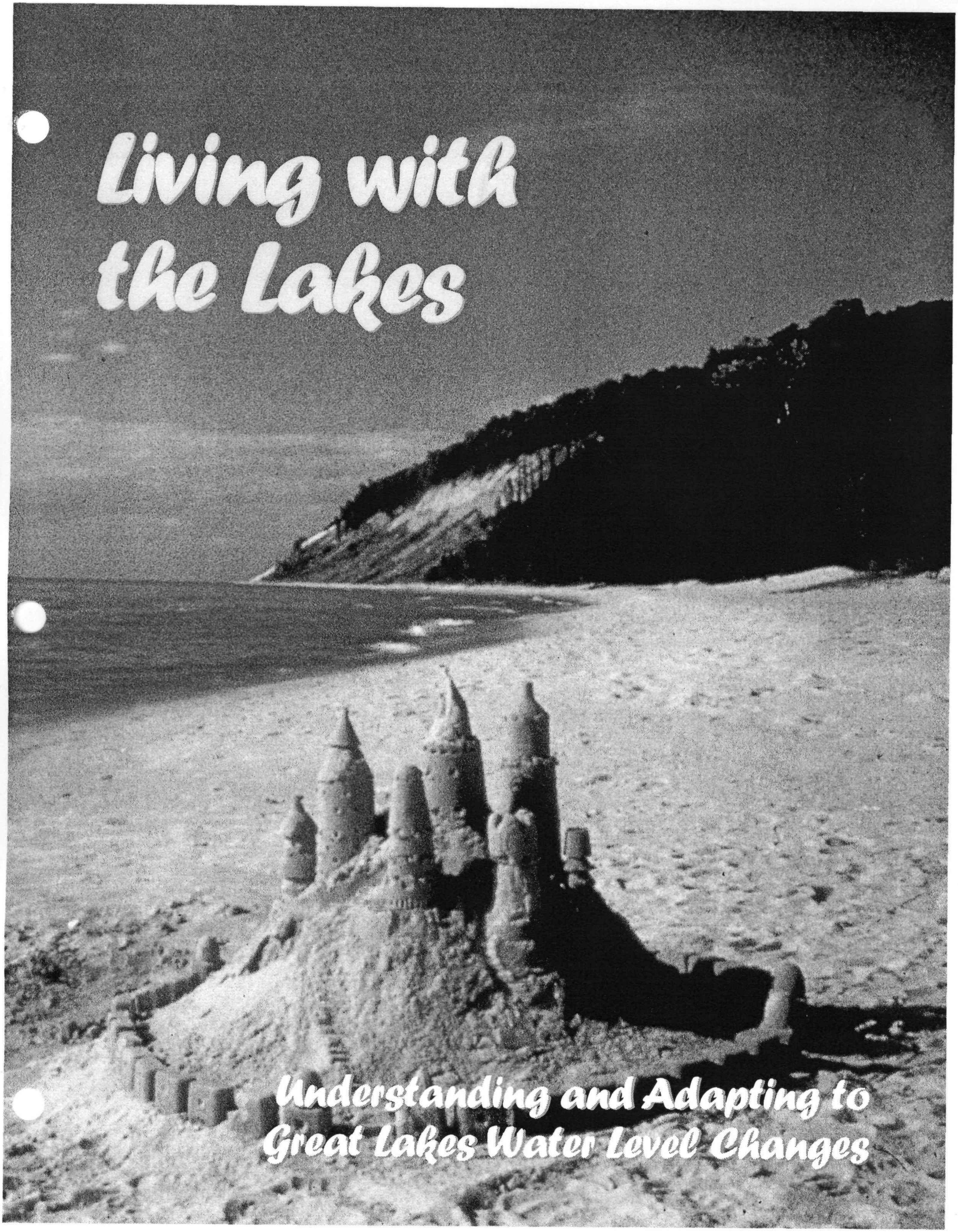
Exhibit B

Living With the Lakes – Understanding and Adapting to Great Lakes Water Level Changes, U.S. Army Corps of Engineers and Great Lakes Commission, (1999)

Living with the Lakes



Understanding and Adapting to Great Lakes Water Level Changes

US Army Corps of Engineers
Detroit District

The Detroit District, established in 1841, is responsible for water resource development in all of Michigan and the Great Lakes watersheds in Minnesota, Wisconsin and Indiana.

Great Lakes Commission

The Great Lakes Commission is an eight-state compact agency established in 1955 to promote the orderly, integrated and comprehensive development, use and conservation of the water resources of the Great Lakes basin.

Order your copy of *Living with the Lakes*!

MEASUREMENTS CONVERTER TABLE

U.S. to Metric

Length
feet x .305 = meters
miles x 1.6 = kilometers

Volume
cubic feet x 0.03 = cubic meters
gallons x 3.8 = liters

Area
square miles x 2.6 = square kilometers

Mass
pounds x 0.45 = kilograms

Metric to U.S.

Length
meters x 3.28 = feet
kilometers x 0.6 = miles

Volume
cubic meters x 35.3 = cubic feet
liters x 0.26 = gallons

Area
square kilometers x 0.4 = square miles

Mass
kilograms x 2.2 = pounds

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Web: www.glc.org

Also available for downloading from the Great Lakes Information Network (GLIN), Hydrology section:
http://www.great-lakes.net/envt/water/hydro.html

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Contents

Port Huron to Mackinac Race, Lake Huron; Lake Michigan beach at Petoskey, Michigan; and Calumet Sag Channel, Calumet Park, Illinois, on Lake Michigan

As stewards of the natural resources, it is our responsibility to understand the causes and implications of Great Lakes water level changes. Only through this understanding can we make informed decisions and educate future generations about living with the lakes.

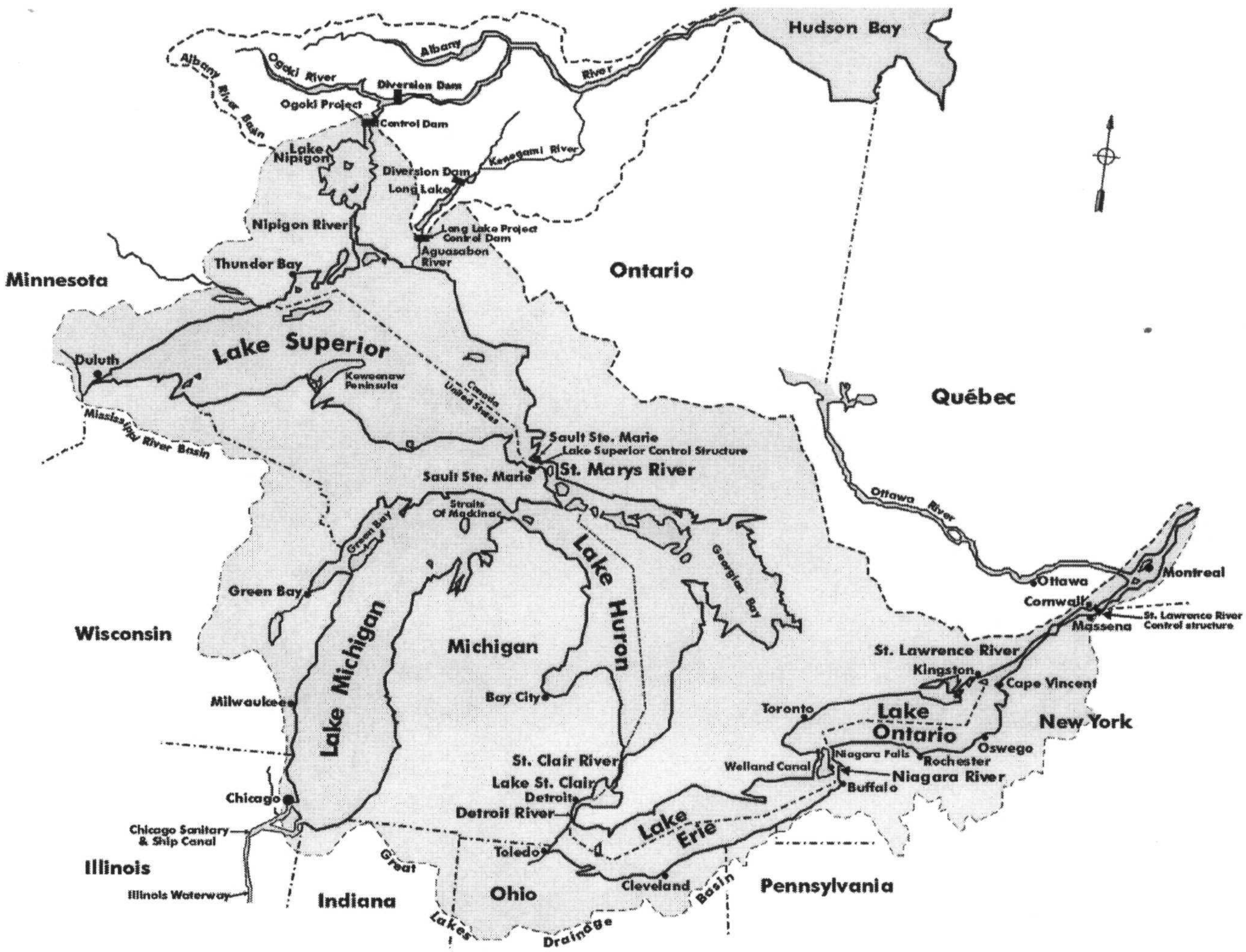
Indiana Dunes State Park, Lake Michigan

Introduction

The Great Lakes-St. Lawrence River system is a dynamic environment, still evolving over time. Ever since the last glaciers retreated more than 10,000 years ago, Great Lakes water levels and outflows have varied dramatically. The Great Lakes affect human activities and all aspects of the natural environment, from weather and climate, to wildlife and habitat. Unlike oceans, where tides are constant and predictable, water levels on the Great Lakes can vary significantly in frequency and magnitude making them difficult to accurately predict.

Satellite image of the Great Lakes and their drainage basins

The Great Lakes - St. Lawrence River system



The Great Lakes - Superior, Michigan, Huron, Erie and Ontario - and their connecting channels and the St. Lawrence River form the largest fresh surface water system on Earth.

Covering more than 94,000 square miles and draining more than twice as much land, the Great Lakes hold an estimated 6 quadrillion gallons of water.

The Great Lakes-St. Lawrence River drainage basin includes part or all of the eight U.S. states of Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York and the Canadian provinces of Ontario and Quebec. More than one-tenth of the population of the United States and one-quarter of the population of Canada inhabit this watershed.

The ecosystem is blessed with huge forests and wilderness areas, rich agricultural land, hundreds of tributaries and thousands of smaller lakes, extensive mineral deposits, and abundant wildlife, including a world-class fishery. The binational region is North America's industrial heartland, and also supports a multi-billion-dollar outdoor recreation and tourism industry, a strong maritime transportation system and a diverse agricultural base.

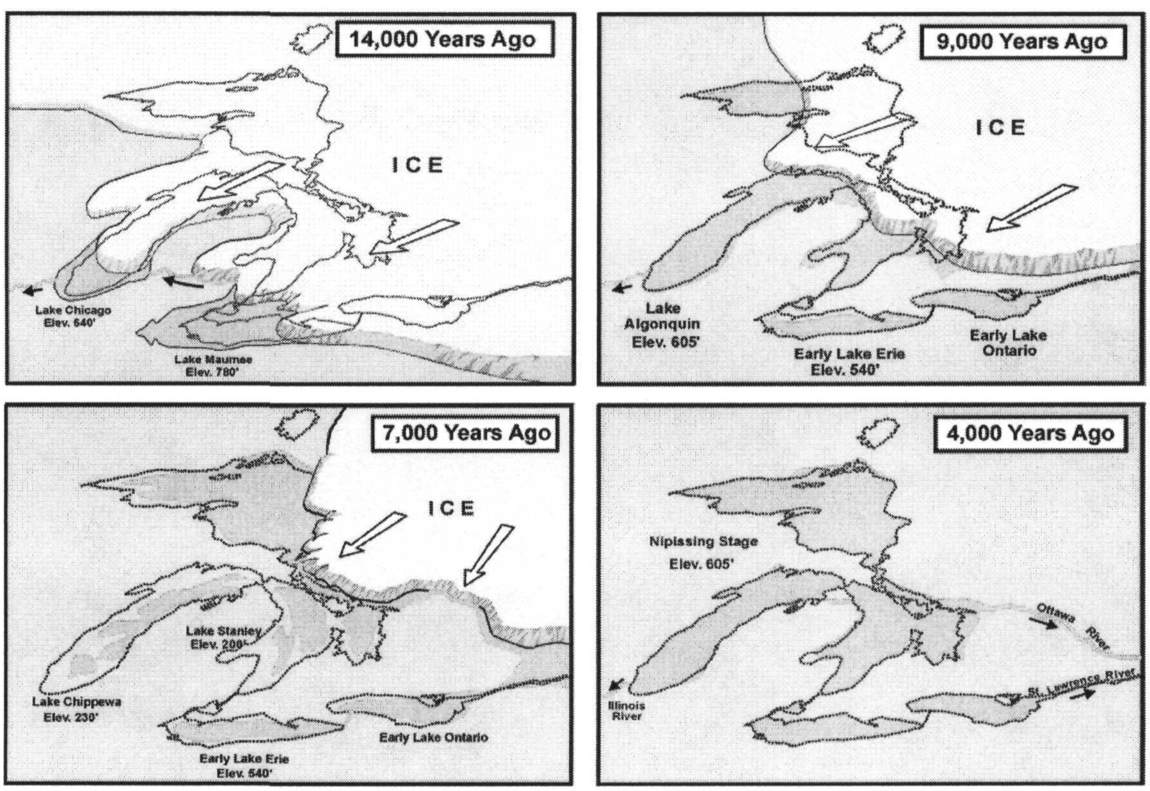
How the lakes were formed

About a billion years ago, a fracture in the earth running from what is now Oklahoma to Lake Superior generated volcanic activity that almost split North America. Over a period of 20 million years, lava intermittently flowed from the fracture. This geomorphic age created mountains covering the regions now known as northern Wisconsin and Minnesota, and the Laurentian mountains were formed in eastern Canada. Over time these mountains eroded, while occasional volcanic activity continued. Molten magma below the highlands of what is now Lake Superior spewed out to its sides, causing the highlands to sink and form a mammoth rock basin that would one day hold Lake Superior. Eventually the fracture stabilized and, over time, the rock tilted down from north to south.

The region went from fire to ice with the arrival of the glaciers, which advanced and retreated several times over the last 5 million years. During the periods of glaciation, giant sheets of ice flowed across the land, leveling mountains and carving out massive valleys. Where they encountered more resistant bedrock in the north, only the overlying layers were removed. To the south, the softer sandstones and shales were more affected. As the glaciers melted and began receding, their leading edges left behind high ridges, some of which can be seen today in the cliffs of Door County, Wisconsin, and the Bruce Peninsula in Ontario. Huge lakes formed between these ridges from the retreating ice fronts, and continually changed over time as the ice sheet moved northward.

Early drainage from these lakes flowed southward through the present Illinois River Valley toward the Mississippi River, through the Trent River Valley between present lakes Huron and Erie and through the Lake Nippissing-Ottawa River Valley from Georgian Bay on Lake Huron downstream to the present Montreal, Quebec, area.

The glaciers began to retreat almost 14,000 years ago. Most of the icefields left the Great Lakes region about 7,000 - 9,000 years ago.



Prehistoric glacial movements and lake shapes

Pt. Aux Barques, Michigan, on Lake Huron

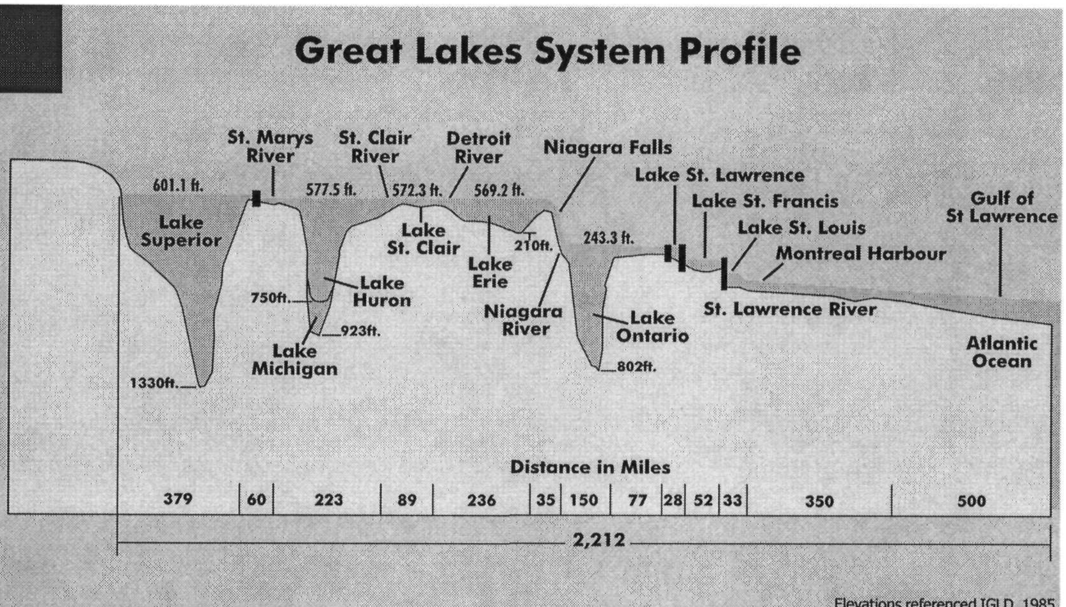
Even today, virtually all of the land in the Great Lakes basin continues to rise.

Without the immense weight of the glaciers—thousands of feet thick in places— the land began to rebound. Even today, virtually all of the land in the Great Lakes basin continues to rise. Southern parts of the basin are rising slightly, less than 3 inches per century. The northeastern corner of the Lake Superior basin, however, is rebounding in excess of 21 inches per century. *(See description of crustal rebound on page 17.)*

Since the retreat of the glaciers, water levels continued to undergo dramatic fluctuations, some in the magnitude of hundreds of feet. These extremes were caused by changing climates, crustal rebound and natural opening and closing of outlet channels. Within the last 1,000 years, evidence suggests that lake levels exceeded the range of levels recorded since 1865 by an additional five feet on lakes Michigan and Huron. As a consequence of these recent fluctuations, shoreline position and environments have dramatically changed. Dunes, baymouth barriers, embayments and river mouths have all been modified by the forces of water. Many dune formations—some hundreds of feet thick—were established during glacial periods. The tops of these dunes have been continuously sculpted by winds to form the majestic structures now visible.

Today, rebounding of the earth's crust, erosion, and changes in climate continue to alter the shapes and sizes of the Great Lakes. As one of the youngest natural features on the North American continent, the lakes remain a dynamic, evolving system.

The Great Lakes and connecting channels



Four of the five Great Lakes are at different elevations, leading like a series of steps toward the Atlantic Ocean. The five individual lakes are connected to each other through channelways, forming one system. Water continually flows from the headwaters of the Lake Superior basin through the remainder of the system.

The St. Marys River is a 60-mile waterway flowing from Lake Superior down to Lake Huron, descending more than 20 feet in elevation. Lakes Michigan and Huron are connected by the deep Straits of Mackinac and are considered to be one lake hydraulically with lake levels rising and falling together. The St. Clair and Detroit rivers, and Lake St. Clair between them, form an 89-mile-long channel connecting Lake Huron with Lake Erie. The fall between Lake Huron and Lake Erie is only about 8 feet. The 35-mile Niagara River links lakes Erie and Ontario, with the majority of the 325-foot difference in elevation occurring at Niagara Falls. The man-made Welland Canal also links the two lakes, providing a detour around Niagara Falls. From Lake Ontario, water flows into the St. Lawrence River, which converges with the Ottawa River near Montreal to flow to the Atlantic Ocean.

Lake Michigan in Indiana

People and the Great Lakes

Plentiful water and game have drawn people to the Great Lakes region for nearly 10,000 years.

People arrived in the Great Lakes basin about 10,000 years ago. By the 1500s, an estimated 60,000 to 120,000 aboriginal people lived in the area. The fertile soils, plentiful water and game supported the native people, who took to the lakes and tributaries in their birch bark canoes. In the north, they mined copper, using rocks to hammer pure chunks from the bedrock; this copper made its way by trade as far as present-day New York. The descendants of these first inhabitants were to become many current Native American Indian tribes, including the Oneida, Mohawk, Wyandot, Chippewa, Iroquois, Algonquin, Menominee, Ojibwa, Ottawa, Potawatomi and Winnebago.

By the early 1600s, explorers, missionaries and fur traders arrived, with Lake Huron the first of the Great Lakes to be seen by Europeans. Samuel de Champlain called the lake *La Mer Douce*, "the sweetwater sea."

French fur traders followed the water routes used by the Indians, traveling the lakes in their canoes with loads of beaver and other pelts bound for east coast settlements and Europe. Some of these canoes carried crews of six to 12 voyageurs and loads of more than 5,000 pounds. The French established bases, and later military forts, to protect the fur trade. The British followed suit, opening the way for settlement. The fur trade lasted until the early 1800s, followed by a logging campaign that stripped vast areas of virgin forests from most of the watersheds.

Consumptive uses

Uses of Great Lakes resources have all had profound impacts on the regional landscape and ecosystems. Many of these uses affect the quality of the water resources available, while some can affect the quantity of water throughout the system.

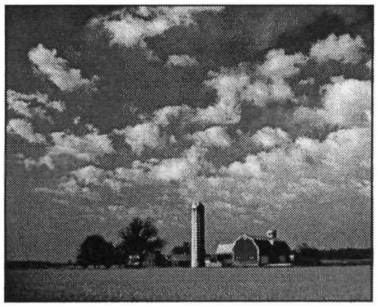
The term **consumptive use** refers to any quantity of water that is withdrawn from the Great Lakes system and not returned. Current consumptive uses of the lakes include drinking water for humans and livestock, irrigation and industrial uses. Due to the large volume of water in the Great Lakes, consumptive use has only a minor effect on water levels.

Drinking water

Municipalities throughout the Great Lakes basin draw tens of billions of gallons of water per day from the Great Lakes to satisfy their public water supply needs. Public water supply systems provide water to homes, schools and offices, as well as to industrial facilities and businesses. The average household uses 100 gallons of water per person per day. In addition, millions of people in both rural and urban areas of the Great Lakes basin rely on groundwater for their sole supply of water. Groundwater is important to the Great Lakes ecosystem, serving as a reservoir that replenishes the lakes in the form of base flow in tributaries.

Industry

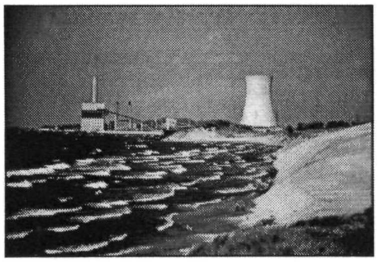
It's no coincidence that most of the region's large industrialized urban areas are located on the shores of the Great Lakes, not only because of transportation advantages but because of the seemingly inexhaustible supply of freshwater for domestic and industrial use. In fact, half of Canadian manufacturing and one-fifth of U.S. manufacturing is based on the region's freshwater coast. The binational Great Lakes region accounts for approximately 60 percent of steel production in North America. The pulp and paper industry also demands large quantities of water in its manufacturing operations. About 10 percent of the water used in industrial processes is consumed, with the remainder returned to the watershed following treatment.



A farm in Michigan in the Lake Erie drainage basin

Agriculture

Agriculture in the Great Lakes region is diverse and productive, with grain, corn, soybeans, dairy, and livestock as the region's mainstays. Unique climate niches have created a wealth of specialty crops. For example, the western shore of Michigan's lower peninsula provides excellent conditions for orchards and vineyards. Today, about one-third of the land in the basin is used for agriculture, supporting nearly 25 percent of the total Canadian agricultural production and 7 percent of the U.S. production. Irrigation represents a modest but growing consumptive use of Great Lakes water.



Power plant and dunes on Lake Michigan shoreline in Indiana

Thermoelectric power

Fossil fuel and nuclear power plants around the lakes use water for cooling equipment and to produce steam to drive turbines. Less than 2 percent of these withdrawals are consumed, lost primarily through evaporation. The remainder is returned to the lakes.

Nonconsumptive uses

Nonconsumptive use refers to any water withdrawal or instream use in which the entire quantity is returned to the system. Nonconsumptive uses of the lakes include transportation, hydroelectric power generation and water-based recreation.

Recreational boating, sport fishing and commercial fishing

The Great Lakes offer outstanding tourism and recreation opportunities, ranging from wilderness areas such as Isle Royale, a U.S. island national park, to waterfront parks in major cities. A well-defined four-seasons climate supports many types of outdoor recreation, from ice fishing in the winter to boating, swimming and fishing in the summer. The eight Great Lakes states have about 3.7 million registered recreational boats, or about a third of the nation's total. Michigan and Minnesota lead the U.S. in the number of boat registrations, and six Great Lakes states rank in the nation's top ten in total number. Approximately a million recreational boats ply the U.S. waters of the Great Lakes each year. The commercial and sport fishing industry is collectively valued at more than $4 billion annually.

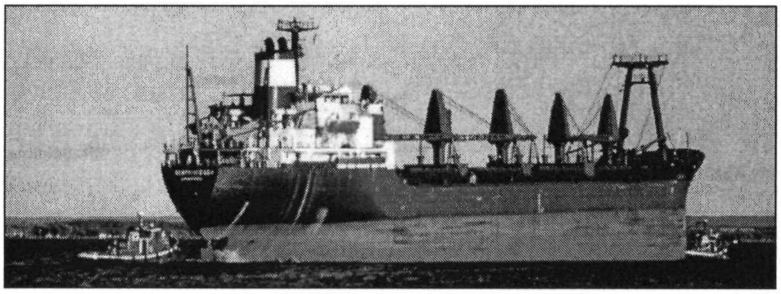
Charter fishing on Lake Michigan

Commercial fishing in Duluth, Minnesota, on Lake Superior

Hydroelectric power

Hydroelectric power generation is by far the largest instream use for Great Lakes water. Hydroelectric power production at plants located on the St. Marys, Niagara and St. Lawrence rivers is dependent upon the "head" or difference between upstream and downstream water levels. During most periods, differences in these levels are relatively constant and power production is not significantly affected. During periods of significant increases in outflows from a lake, power production can increase substantially. The converse is true under very low outflow conditions. Utilities also use coal, oil, natural gas and nuclear power to produce electricity in the Great Lakes region.

Shipping



Ocean-going vessel in Duluth, Minnesota - Superior, Wisconsin, Harbor on Lake Superior

The Great Lakes and St. Lawrence River are part of a vast system linking North America's heartland with ports and markets throughout the world. The world's longest deep-draft inland waterway, the system extends from Duluth, Minnesota, on Lake Superior, to the Gulf of St. Lawrence on the Atlantic, a distance of more than 2,340 miles. This shortcut to the continent's interior was made possible with the construction of a ship canal and lock system opened in 1855 at Sault Ste. Marie, Michigan, the development of the Welland Canal since 1829, and the completion of the St. Lawrence Seaway in 1959.

Crooked Lake, Emmet County, Michigan: One of thousands of inland lakes in the Great Lakes basin

Natural Factors

The difference between the amount of water coming into a lake and the amount going out is the determining factor in whether the water level will rise, fall or remain stable. When several months of above-average precipitation occur with cooler, cloudy conditions that cause less evaporation, the levels gradually rise. Likewise, prolonged periods of lower-than-average precipitation and warmer temperatures typically result in lowering of water levels.

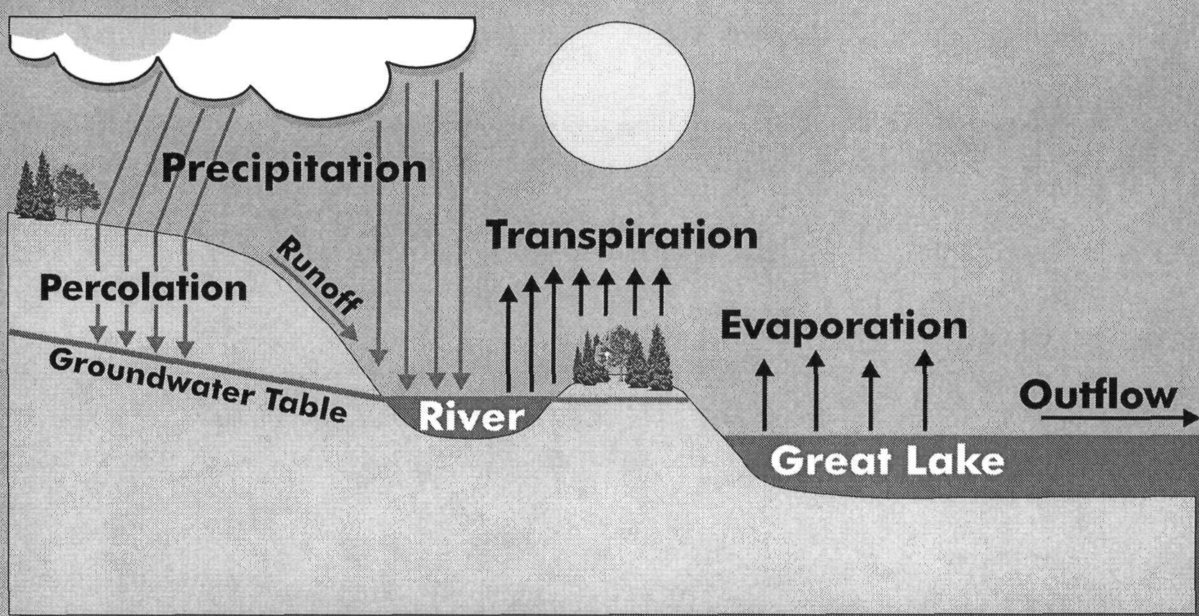
Grand Haven, Michigan, lighthouse on Lake Michigan during storm

The hydrologic cycle

Water, a renewable resource, is continually recycled and returned to the ecosystem through the hydrologic cycle. Moisture is carried into the Great Lakes basin most commonly by continental air masses, originating in the northern Pacific Ocean, that traverse the North American continent. Tropical systems originating in the Gulf of Mexico or Arctic systems originating in the north polar region also carry moisture into the basin. As weather systems move through, they deposit moisture in the form of rain, snow, hail or sleet. Water enters the system as precipitation directly on the lake surface, runoff from the surrounding land including snowmelt, groundwater, and inflow from upstream lakes. Precipitation falling on the land infiltrates into the ground through percolation to replenish the groundwater.

Water leaves the system through evaporation from the land and water surface or through transpiration, a process where moisture is released from plants into the atmosphere. Water also leaves the system by groundwater outflow, consumptive uses, diversions and outflows to downstream lakes or rivers. Ultimately water flows out of each of the Great Lakes through their connecting channels and the St. Lawrence River to the Atlantic Ocean.

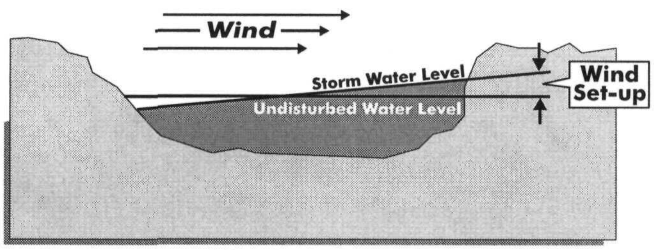
Evaporation from the lake surface is a major factor in the hydrologic cycle of the Great Lakes. Water evaporates from the lake surface when it comes in contact with dry air, forming water vapor. This vapor can remain as a gas, or it can condense and form water droplets, causing fog and clouds. Some of this moisture returns in the form of rain or snow, completing the hydrologic cycle. The best example of this is lake-effect snow squalls, which commonly occur on the leeward side of most lakes. Generally, much of the evaporated water is removed from the system by prevailing wind patterns.



Hydrologic Cycle

Short-term fluctuations

Some water level fluctuations are not a function of changes in the amount of water in the lakes. These fluctuations, generally short in duration, are due to winds or changes in barometric pressure. Short-term fluctuations, lasting from a couple hours to several days, can be very dramatic. Fluctuations due to storms or ice jams are two examples.



Lake profile showing wind set-up

There are three kinds of water level fluctuations: short-term, seasonal and long-term.

Wind set-up, storm surge and seiche

Sustained high winds from one direction can push the water level up at one end of the lake and make the level drop by a corresponding amount at the opposite end. This is called wind set-up or storm surge. Changes in barometric pressure can add to this effect. When the wind abruptly subsides or barometric pressure changes rapidly, the water level often will oscillate until it stabilizes again. This phenomenon is known as **seiche** (pronounced "sayshe"). The pendulum-like movements within seiches can continue for days after the forces that created them vanish. Lake Erie is most susceptible to storm surges and seiches due to its east-west orientation in an area of prevailing westerly winds and its generally shallow western end.

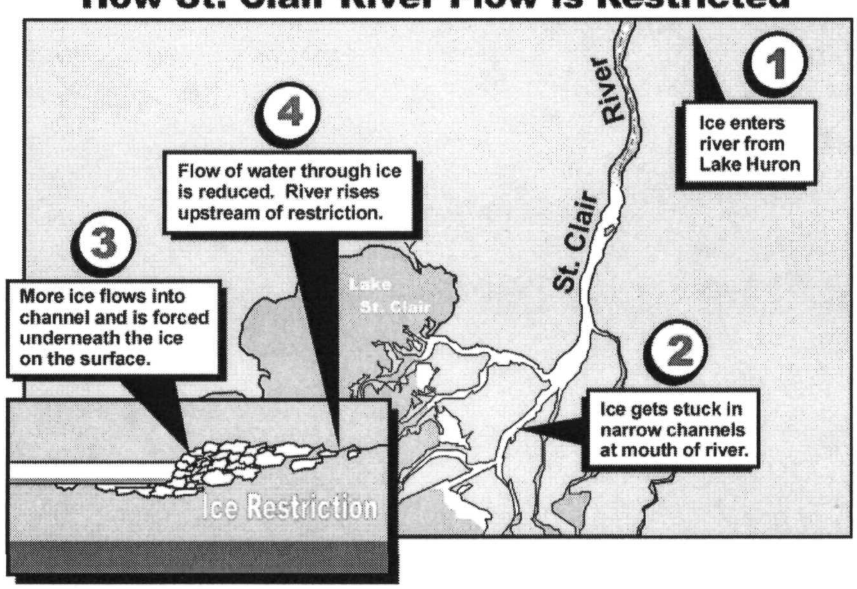
Plant growth and ice development in the connecting channels

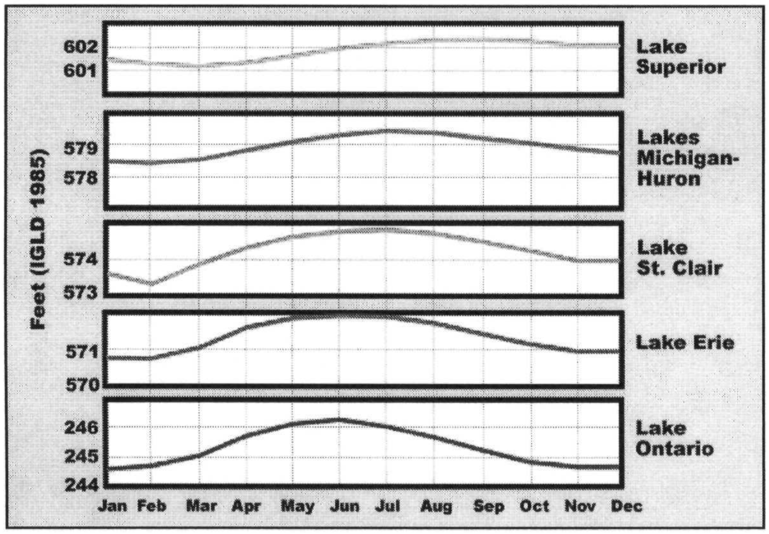
The natural growth of aquatic plants can affect the flow of water in the tributaries and connecting channels of the lakes. Plant growth decreases the flow of water by narrowing or partially obstructing the channel through which the water flows. Plant growth in part depends on the weather, and can vary from month to month and year to year. In the summer, aquatic plant growth in the Niagara River reduces its flow, on average, by about 2 percent.

An ice jam in an outlet river can drastically slow the flow of water out of one lake and into another. Water levels rise upstream of the jam and fall downstream. The effects are most noticeable on the water levels of the affected river, and of smaller lakes such as St. Clair and Erie.

On the St. Clair River, normal ice build-up can reduce the flow in the river by about 5 percent during the winter. A serious ice jam can reduce flows by as much as 65 percent for short periods of time. Ice jams can develop in a matter of hours, but it may take several days for the jam to be relieved and water levels and flows to return to normal.

How St. Clair River Flow is Restricted





Seasonal fluctuations

The lakes are generally at their lowest levels in the winter months. In the fall and early winter, when the air above the lakes is cold and dry and the lakes are relatively warm, evaporation from the lakes is greatest. With more water leaving the lakes than entering, the water levels decline to their seasonal lows.

As the snow melts in the spring, runoff to the lakes increases. Evaporation from the lakes is least in the spring and early summer when the air above the lakes is warm and moist and the lakes are cold. At times, condensation on the lake surface replaces evaporation. With more water entering the lakes than leaving, the water levels rise. The levels peak in the summer. In the early fall, evaporation and outflows begin to exceed the amount of water entering the lakes.

The range of seasonal water level fluctuations on the Great Lakes averages about 12 to 18 inches from winter lows to summer highs.

The range of seasonal water level fluctuations on the Great Lakes averages about 12 to 18 inches from winter lows to summer highs. The timing of the annual peaks and lows varies geographically due to differences in climate across the basin. Seasonal rises begin earlier on the more southern lakes where it is warmer with peaks usually occurring in June or July. Lake Superior, the northernmost lake, is generally the last lake to peak, usually in August or September.

All water levels on the Great Lakes are measured relative to sea level and expressed relative to the International Great Lakes Datum (IGLD), last updated in 1985. *(For further information on the reference datum, see page 27.)*

Weather in the Great Lakes basin

"Wait a day and the weather will change" is an apt description of weather in the Great Lakes region, especially in the spring and fall. That's because the region is affected by both warm, humid air from the Gulf of Mexico and cold, dry air from the Arctic. In general, the north experiences cooler weather, while the south has warmer temperatures. The entire basin experiences four distinct seasons.

The Great Lakes also have a significant influence on the climate. Acting as a giant heat sink, the lakes moderate the temperatures of the surrounding land, cooling the summers and warming the winters. This results in a milder climate in portions of the basin compared to other locations of similar latitude. The lakes also act as a giant humidifier, increasing the moisture content of the air throughout the year. In the winter, this moisture condenses as snow when it reaches the land, creating heavy snowfall in some areas, known as "snow belts" on the downwind shores of the lakes. The shores of Lake Superior are particularly prone to this "lake-effect" snow. Some areas around the lake have recorded more than 350 inches of snow in a single year. During the winter, the temperature of the lakes continues to drop. Ice frequently covers Lake Erie but seldom fully covers the other lakes.

Long-term fluctuations

Long-term fluctuations occur over periods of consecutive years and have varied dramatically since water levels have been recorded for the Great Lakes. Continuous wet and cold years will cause water levels to rise. Conversely, consecutive warm and dry years will cause water levels to decline. Water levels have been measured on the Great Lakes since the 1840s. Older records may not be as accurate as current observations, since measurements were only taken at a single gage per lake until 1918 and observations were not taken as frequently as they are today.

Over the last century, the range from extreme high to extreme low water levels has been nearly 4 feet for Lake Superior and between 6 and 7 feet for the other Great Lakes.

The Great Lakes system experienced extremely low levels in the late 1920s, mid-1930s and again in the mid-1960s. Extremely high water levels were experienced in the 1870s, early 1950s, early 1970s, mid-1980s and mid-1990s. Long-term fluctuations are shown on the hydrograph presented on the graph on the following page. A **hydrograph** is a plot of water levels versus time.

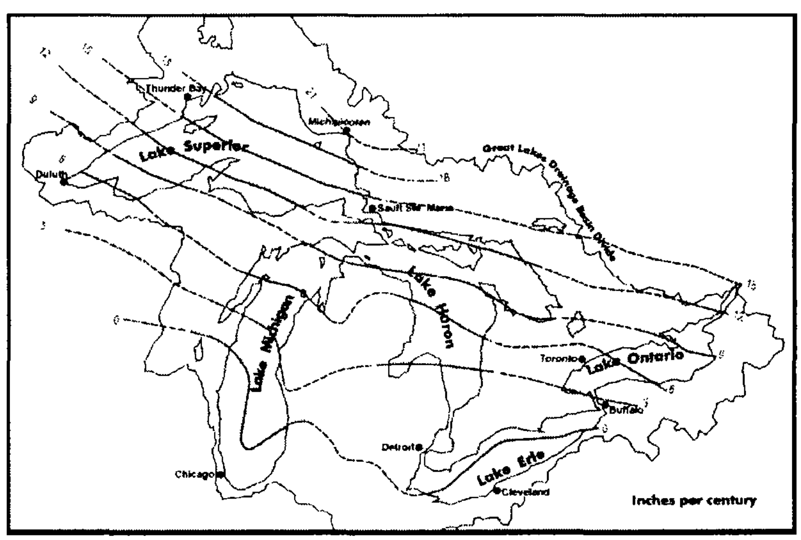
Global warming and a phenomenon known as the 'greenhouse effect' could cause significant changes in long-term lake levels. Although debatable, most predictions indicate that global warming would cause prolonged declines in average lake levels into the future. These declines could create large-scale economic concern for virtually every user group in the Great Lakes basin. Dramatic declines also could compromise the ecological health of the Great Lakes, particularly in the highly productive nearshore areas.

Besides natural climatic variability and potential man-made climate change, other factors can affect long-term fluctuations, including changes in consumptive use, channel dredging or encroachment and crustal movement.

Crustal movement

Crustal movement, the rebounding of the earth's crust from the removed weight of the glaciers, does not affect the amount of water in a lake, but rather affects water levels at different points around the lake. Crustal rebound varies across the Great Lakes basin. The crust is rising the most, more than 21 inches per century, in the northern portion of the basin, where the glacial ice sheet was the thickest, heaviest and the last to retreat. There is little or no movement in the southern parts of the basin. As a result, the Great Lakes basin is gradually tipping, a phenomenon most pronounced around Lake Superior.

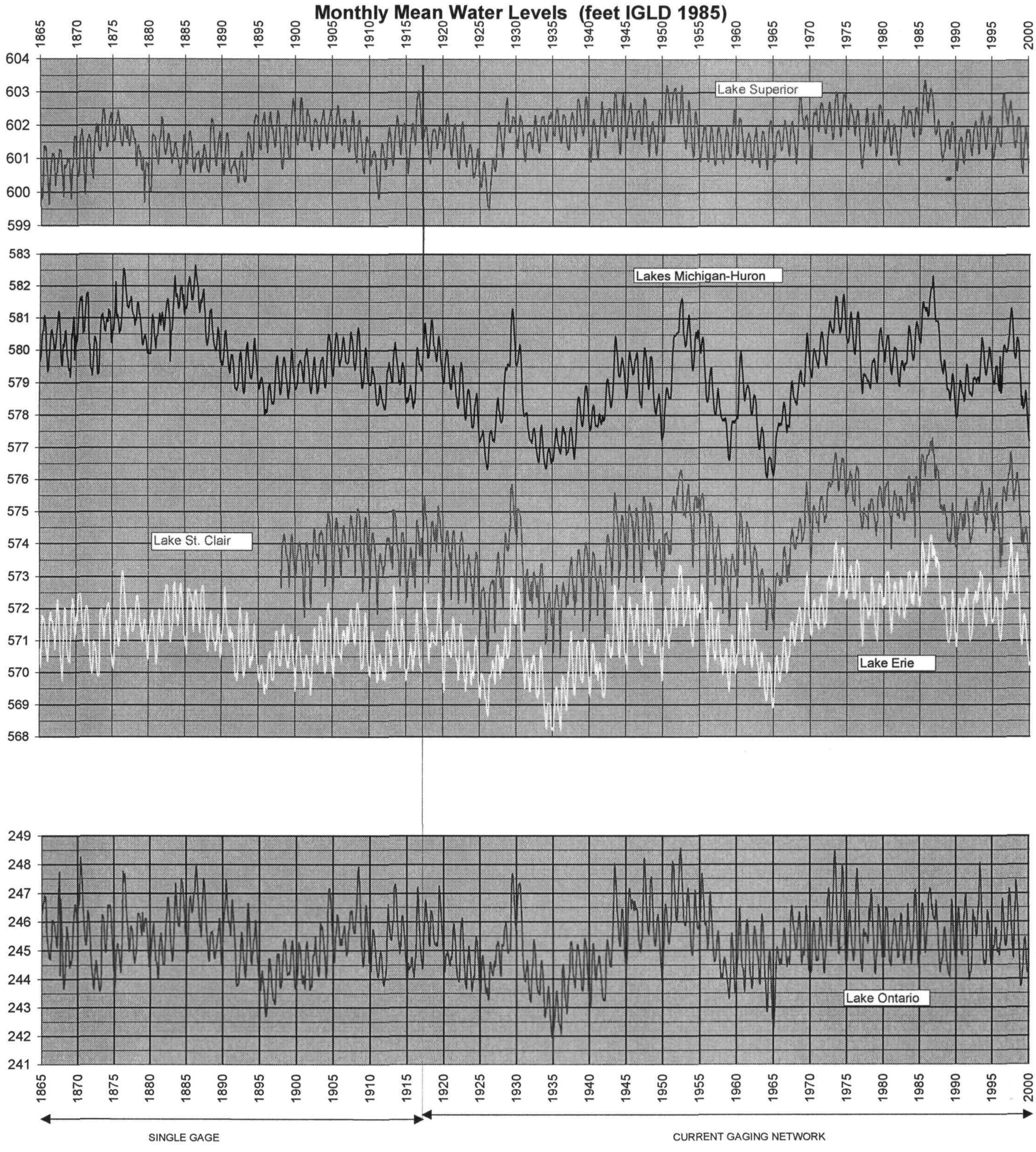
To see what this means for water levels, an analogy can be made using a cup of water. As the cup is tipped, the surface of the water comes closer to the edge of the cup on one side and is farther from the edge on the other side. This is why water levels are measurably higher today at Duluth, Minnesota, and lower at Michipicoten, Ontario, on the opposite side of Lake Superior, than they were several decades ago. This tipping phenomenon is particularly significant for Lake Superior, and somewhat lesser for lakes Michigan, Erie and Ontario as their outlet channels are rising faster than the western shores of these lakes. As such, there is a gradual decrease in outflow capacities for each of the lakes over time.



Rates of crustal rebound

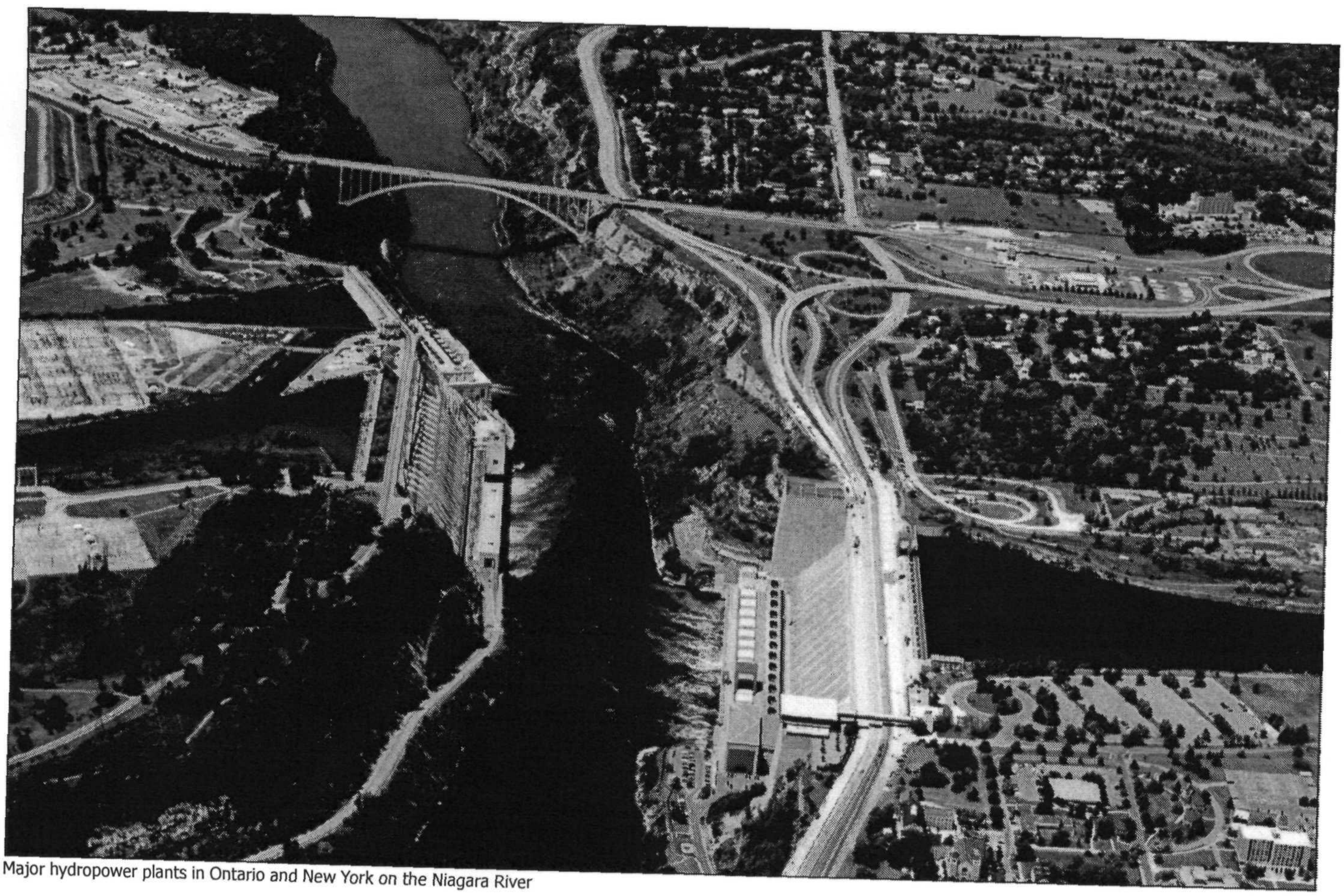
Great Lakes system historical levels

A hydrograph is a plot of lake levels versus time. These hydrographs show monthly average water levels for each of the Great Lakes and Lake St. Clair. Levels have been measured on most lakes since 1865, with the present network of water level gages operating since 1918. Lake levels change seasonally each year and can vary dramatically over longer periods. Short-term fluctuations are of a greater magnitude than the monthly averages.



Human Influence on the System

The Great Lakes are like a series of interconnected bathtubs. Their outlets are like the drains in the tubs. Outflows increase as water levels rise in an upstream lake, but are limited by the size of their outlet channels. As water moves through the Great Lakes-St. Lawrence River system, it passes through progressively larger outlets draining all the lakes above it in the system. The outlet from Lake Superior, at the top of the system, moves about 76,000 cubic feet of water per second on average. By comparison, the outlet from Lake Ontario, the last lake in the chain, moves about 243,000 cubic feet per second on average.



Major hydropower plants in Ontario and New York on the Niagara River

Lake Superior and St. Marys River

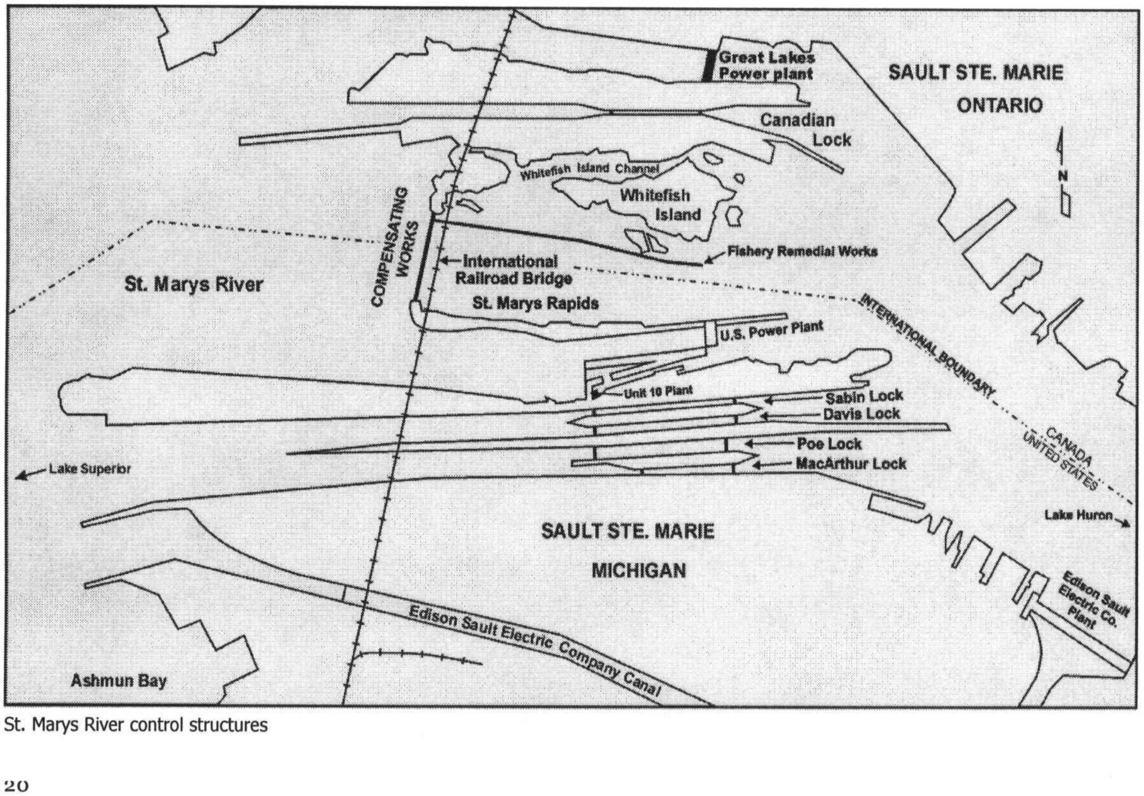
A rock ledge at the head of the St. Marys Rapids provided a natural control for Lake Superior outflows. The rock ledge acted like a weir permitting flows to increase and decrease as Lake Superior's levels rose or fell.

The outflow from Lake Superior is controlled near the twin cities of Sault Ste. Marie, Ontario and Michigan. The outflow began to be changed as early as 1822, when water was diverted from above the St. Marys Rapids for operation of a sawmill. A ship canal was constructed in 1855. Subsequently, various expansions to these facilities took place.

The current flow control facilities consist of three hydropower plants, five navigation locks and a 16-gated control structure, called the Compensating Works, at the head of the St. Marys Rapids. Since the Compensating Works were completed in 1921, Lake Superior outflows have been regulated by humans. This regulation is carried out by the International Lake Superior Board of Control in accordance with conditions specified by the International Joint Commission (IJC). The IJC, a binational agency of the United States and Canada, is responsible for ensuring that the outflow regulation meets the terms of the Boundary Waters Treaty of 1909 between the two nations.

Lake Superior's outflows are adjusted monthly, taking into consideration the water levels of lakes Superior and Michigan-Huron. The objective is to help maintain the lake levels both on Lake Superior and lakes Michigan and Huron in relative balance compared to their long-term seasonal averages. For example, if the Lake Superior level is above its average and the level of lakes Michigan-Huron is below its average, outflows will increase. Converse conditions would lead to decreases in outflows.

The regulated outflow is achieved by adjusting the flows through the three hydropower plants and the 16-gate Compensating Works, after requirements are met for lockages, the St. Marys Rapids fishery and industries at Sault Ste. Marie, Michigan and Ontario. At a minimum, one gate is kept half-open at the Compensating Works to maintain water in the St. Marys Rapids critical for fish spawning. More gates are opened when flows in the river exceed the capacities of the hydropower plants.



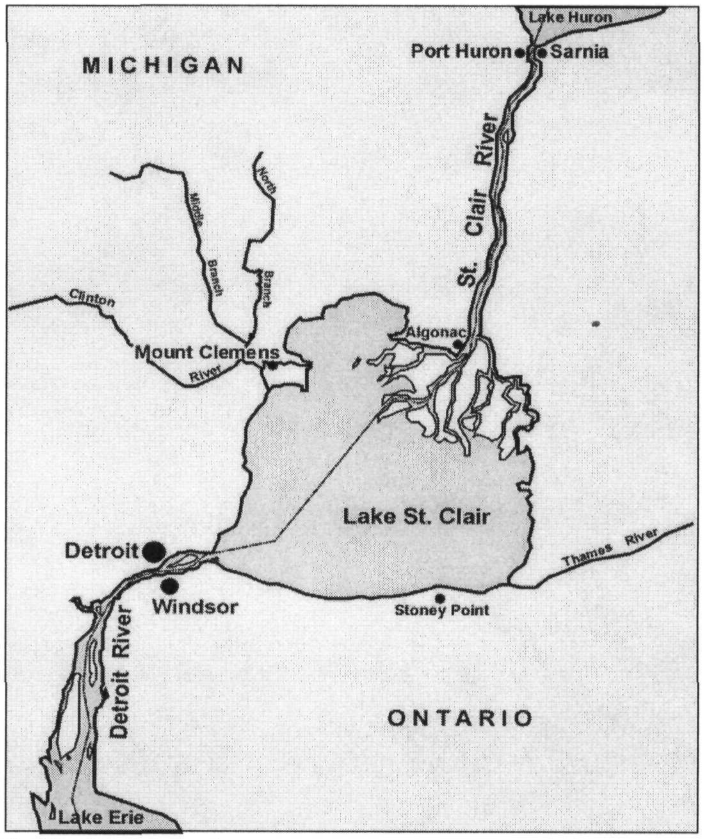
St. Marys River control structures

Lake Superior outflows have averaged 76,000 cubic feet per second (cfs) per month and have been as high as 132,000 cfs and as low as 41,000 cfs per month.

St. Clair River, Lake St. Clair and Detroit River

The St. Clair, Lake St. Clair and Detroit River system is naturally regulated; flows in the St. Clair and Detroit rivers are limited by the size of their channelways and the levels of Lake Huron upstream and Lake Erie downstream.

The St. Clair River is an interconnecting channel between lakes Huron and St. Clair, running approximately 39 miles from its head between Port Huron, Michigan, and Sarnia, Ontario to its very extensive delta in Lake St. Clair. The St. Clair River has a 5-foot fall over this distance. Flows have averaged 182,000 cfs since records have been kept. During extreme conditions, flows have been recorded as high as 232,000 cfs and as low as 106,000 cfs per month.



St. Clair - Detroit river system

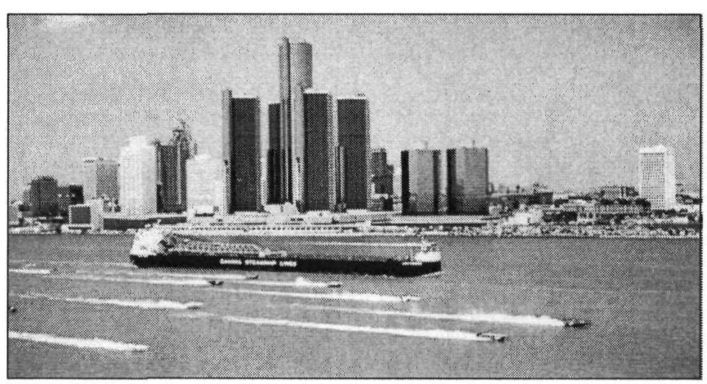
Although not a Great Lake, Lake St. Clair is an extremely important body of water to millions of users. It receives inflow from the St. Clair River and, to a minor degree, from tributary rivers such as the Clinton River in Michigan and the Thames River in Ontario. The lake's average depth is less than 20 feet. Due to its being shallow and nearly round in shape, Lake St. Clair is highly susceptible to rapid changes in wind and wave patterns, storm surges and lake level changes.

The Detroit River receives inflow from Lake St. Clair and discharges into the west end of Lake Erie, running approximately 32 miles. Over this distance, the water surface drops nearly 3 feet. The flow in the Detroit River has averaged 186,000 cfs since records have been maintained. During extreme conditions, flows have been as high as 238,000 cfs per month or as low as 112,000 cfs per month.

Flows in the St. Clair River, Lake St. Clair and Detroit River are naturally regulated.

Dredging in the St. Clair-Detroit system began in the 1930s and continued through the 1950s to deepen navigation channels. Dredging is the enlarging or deepening of navigation channels to allow ships to enter and leave ports more efficiently, quickly and safely. Without dredging, most rivers and harbors would be inaccessible for commercial navigation. Dredging has increased the flow capacity of these rivers and, as a result, has permanently lowered the levels of lakes Michigan and Huron by nearly 15 inches. The effect on Lake Erie's water level was temporary.

Flows in both the St. Clair and Detroit rivers can be dramatically reduced for short periods during ice jams. Flows in the Detroit River can virtually stop or even reverse for a few hours during an extreme storm surge at the west end of Lake Erie.

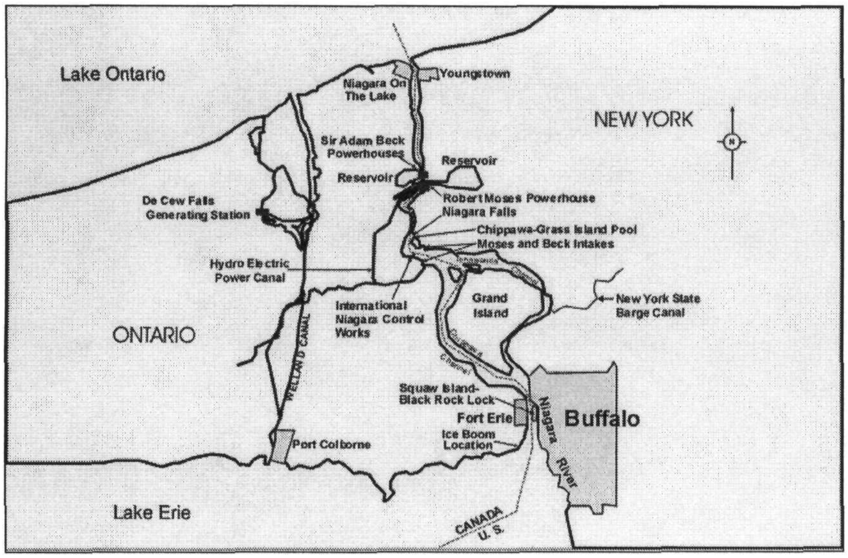

Traffic on the Detroit River at Detroit, Michigan

Niagara River

The Niagara River runs approximately 35 miles between lakes Erie and Ontario. Hydropower plants take advantage of the abundant energy potential represented by the nearly 330-foot difference in elevations between lakes. These facilities are owned and operated by the New York Power Authority, Ontario Power Generation and Canadian Niagara Power. The plants divert water from the Niagara River above Niagara Falls and return it to the river below them.

To ensure that sufficient water continues to go over the falls to maintain their scenic beauty, the United States and Canada signed the 1950 Niagara River Treaty. This treaty specifies minimum falls flow requirements for tourist and non-tourist hours with the remaining amount of water shared between the United States and Canada for hydroelectric power production.

In accordance with the treaty, a gated structure was built part-way across the river just upstream of the falls to adjust flows to meet the minimum falls requirements and to regulate water levels at the intakes for power generation. This structure does not control the overall amount of water flowing into the river from Lake Erie, only the manner in which it is distributed. Flows in the Niagara River average 203,000 cfs, and have been as high as 265,000 cfs and as low as 116,000 cfs per month since records have been kept.



Niagara River, Welland Canal and hydropower plants

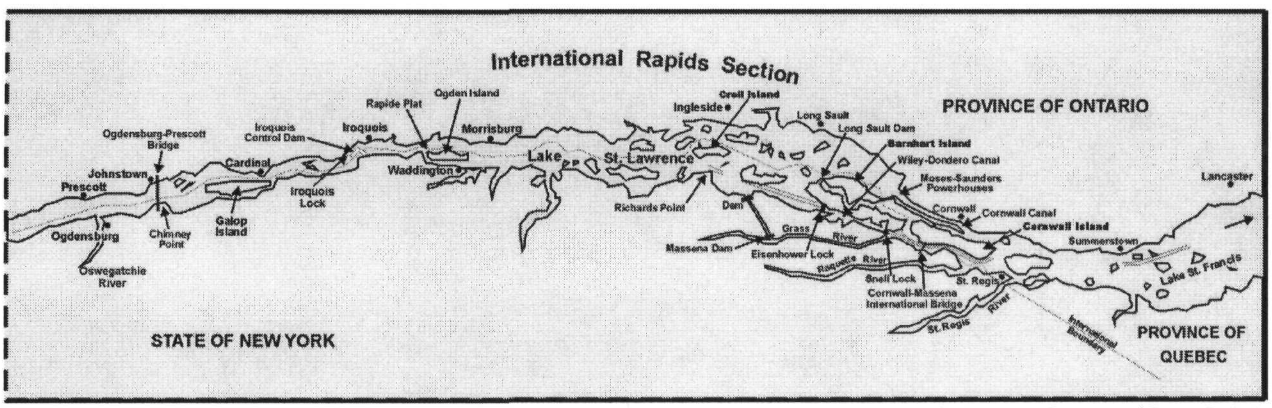
A factor that affects lake levels is man-made construction in the connecting channels between the lakes and in the St. Lawrence River system. This construction includes fills, piers, marinas and other structures built into the river course beyond pre-existing shorelines. Development activities such as these can affect the outflow of a channelway. Although an individual construction project may not have a measurable consequence, continual development over time can have a significant cumulative impact. For example, the mouth of the Niagara River at Fort Erie, Ontario and Buffalo, New York, is an area where encroachment has occurred over the last 100 years. Human activities here have affected Lake Erie water levels by retarding outflows. The magnitude of this retardation is currently under debate.

The outflow from Lake Erie is a function of its elevation, being controlled by a natural rock ledge under the river's mouth between Buffalo, New York, and Fort Erie, Ontario.


Aerial and ground views of Niagara Falls

Lake Ontario and St. Lawrence Seaway and Power Project

The St. Lawrence River is a majestic and expansive river course which drains Lake Ontario. It flows into the Gulf of St. Lawrence of the Atlantic Ocean approximately 540 miles to the northeast, dropping more than 240 feet along its length. The river's course is made up of several important segments. For the first 105 miles, the river is formally called the St. Lawrence Seaway and Power Project. This section is an international body of water shared by the United States and Canada. It includes the beautiful Thousand Islands and Lake St. Lawrence. Downstream of Massena, New York, and Cornwall, Ontario, the river is solely in Canada, flowing for 435 more miles until it reaches the Gulf of St. Lawrence. Near Montreal, Quebec, it receives a vast inflow from the Ottawa River watershed.



St. Lawrence Seaway and Power Project

The outflow from Lake Ontario is managed under the auspices of the IJC and its International St. Lawrence River Board of Control. The IJC's criteria for regulating outflows explicitly recognizes the needs of three major interest groups: riparian (shore property owners), hydropower and commercial navigation. The regulation plans used since 1960 are designed to meet these criteria. Outflows are regulated on a weekly basis.

The outflow from Lake Ontario has been regulated since the completion of the St. Lawrence Seaway and Power Project in 1960.

There are four key objectives of the Lake Ontario regulation plan: 1) maintain the Lake Ontario level within a four-foot range during the navigation season; 2) maintain adequate depths in the International Section of the river for safe navigation; 3) maintain adequate flows for hydropower generation; and 4) protect the lower St. Lawrence River below the control works from flooding. Sometimes when water supplies are extemely high or low, not all of these objectives can be met. For example, Lake Ontario outflows may be limited due to flooding problems downstream around Montreal, Quebec, or if higher flows become a hazard to commercial navigation, particularly upstream of the Massena, New York - Cornwall, Ontario, area.

Diversions

There are five locations on the Great Lakes where water is diverted into, out of or between lake basins.

There are five diversions on the Great Lakes: the Long Lac and Ogoki diversions into Lake Superior, the Lake Michigan diversion at Chicago, and the Welland Canal and New York State Barge Canal between Lake Erie and Lake Ontario. The Welland and New York State Barge Canal do not divert water into or out of the Great Lakes, but rather provide navigation channelways between two of the lakes. Man-made diversions play a minor role in the balancing of Great Lakes water levels when compared to natural forces. The cumulative impacts of all five diversions have raised water levels on Lake Superior by less than 1 inch, had no measurable effect on lakes Michigan-Huron, lowered Lake Erie by almost 4 inches and raised Lake Ontario by less than 1 inch.

Long Lac - Ogoki diversions

The Long Lac and Ogoki diversions take water from the Hudson Bay watershed and augment the natural flows driving hydropower plants in the northern portion of the Lake Superior basin. These projects, in operation since the early 1940s, have increased the water supply to Lake Superior. Combined, these diversions move an average of about 5,300 cfs.

Great Lakes Diversions

Lake Michigan Diversion at Chicago

Since 1848, water has been diverted from Lake Michigan at Chicago, Illinois, for various purposes, including water supply, sewage disposal and commercial navigation. Water from Lake Michigan enters the Chicago Sanitary and Ship Canal, which links the lake through the Illinois Waterway and Des Plaines River to the Mississippi River. Diversion of Lake Michigan waters has varied substantially over the years, and has been the subject of some controversy; several Great Lakes states have gone to court to limit the diversion. Since 1967, the U.S. Supreme Court has limited the diversion to 3,200 cfs averaged over five years.

Welland Canal

The Welland Canal is a deep-draft navigational waterway that joins Lake Erie and Lake Ontario. Originally built in 1829 and since modified several times, the canal allows ships to travel between the two lakes, bypassing the falls and rapids of the Niagara River. The canal also provides water for hydropower generation. Today, this diversion averages about 8,500 cfs.

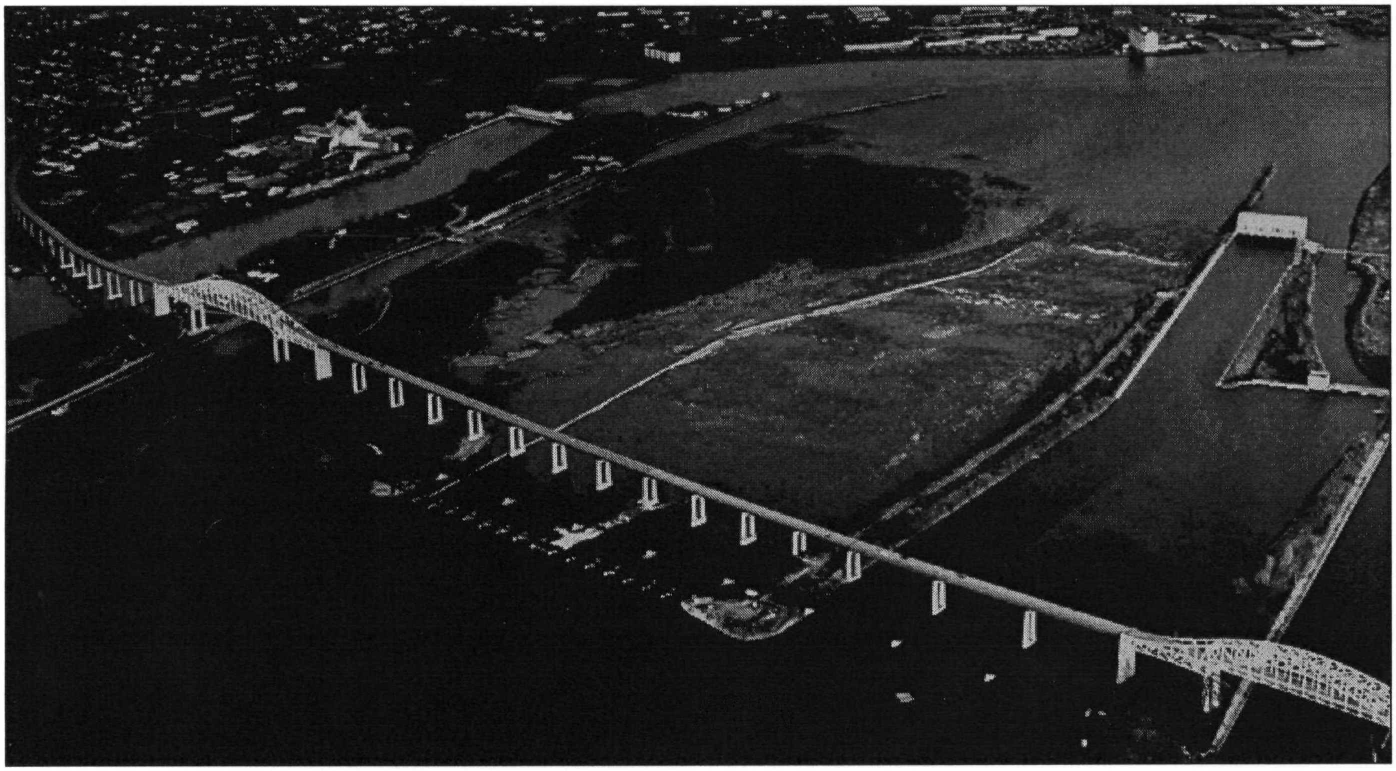
New York State Barge Canal

The New York State Barge Canal is the smallest of the Great Lakes diversions, averaging only about 1,000 cfs. This canal draws its water from the Niagara River at Tonawanda, New York. It has no effect on the water level of or outflow from Lake Erie, but does slightly reduce the flow in the Niagara River below Tonawanda and above the falls. The diverted water is returned to Lake Ontario through four water courses within New York.

Controlling Water Levels

Major factors affecting the water supply to the Great Lakes—precipitation, evaporation and runoff—cannot be controlled or accurately predicted for more than a few weeks into the future. The influences of man-made controls on lake levels are therefore limited. Regulation of outflows from lakes Superior and Ontario have had significant impacts on levels throughout the system since they were introduced. The effects of these artificial controls, however, have been dwarfed by the results of natural climatic variations.

The control of lakes Superior and Ontario outflows are governed by the International Joint Commission's boards of control. Each of the binational control boards has an equal number of members from both countries.



St. Marys Rapids (including the Compensating Works in center foreground), railway bridge and International Bridge; Sault St. Marie, Ontario, in background

How much control is possible?

The Boundary Waters Treaty of 1909 between the United States and Canada provides the principles and mechanisms to help resolve disputes and to prevent future ones, primarily those concerning water quantity and water quality along the boundary between the two countries. The IJC has created boards of control that oversee the operations of the regulatory structures and direct outflows that meet conditions set forth by the IJC to protect the interests of both countries.

The IJC has carried out several studies on water levels issues in response to references, or requests, from the U.S. and Canadian governments. In 1964, when water levels were very low, the governments asked the IJC whether it would be feasible to maintain the waters of all the Great Lakes, including Michigan and Huron, at a more constant level. This study was completed in 1973, when lake levels had risen to record highs. The IJC advised the governments in its report that the high costs of engineering further regulation of lakes Michigan and Huron could not be justified by the benefits. The same conclusion was reached during another study on regulating outflows from Lake Erie in 1983.

In 1985, the IJC released a report on consumptive uses and the effects of existing diversions into and out of the Great Lakes system. Until this study, consumptive use had not been considered significant for the Great Lakes because the volume of water in the system is so large. The study concluded that climate and weather changes affect levels of the lakes far more than existing man-made diversions. However, the report also concluded that if consumptive uses of water continue to increase at historical rates, outflows through the St. Lawrence River could be reduced over time.

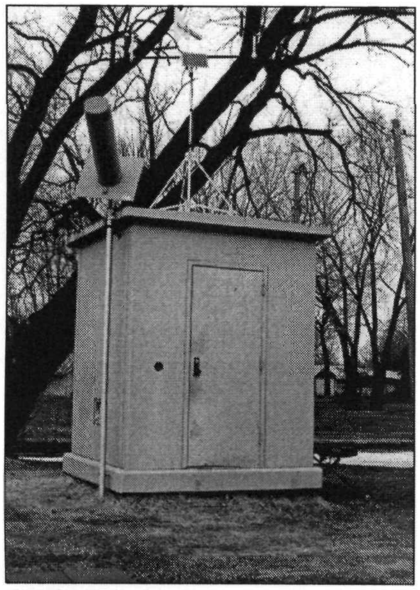
Following the period of high lake levels in the mid-1980s, the IJC conducted a Levels Reference Study on the feasibility of modifying lake levels through various means. In the results of this study, released in 1993, the IJC concluded that the costs of major engineering works to further regulate the levels and flows of the Great Lakes and St. Lawrence River would exceed the benefits provided and would have significant negative environmental impacts. The IJC recommended that comprehensive and coordinated land-use and shoreline management programs needed to be implemented throughout the basin to reduce vulnerability to flood and erosion damages. These recommendations called for state, provincial and local government leadership to help alleviate or minimize property damages under high levels scenarios. Three of the key recommendations were to improve forecast abilities and emergency preparedness plans, to strengthen information databases including extensive monitoring of shoreline erosion, bluff recession and land use, and to initiate comprehensive shoreline management programs.

Left to right: Mackinac Bridge, across the Straits of Mackinac between lakes Michigan and Huron; Lake Superior shoreline in Minnesota; Manistee Breakwall Lighthouse, Manistee, Michigan, on Lake Michigan

Measuring water levels

Water levels are measured and recorded at many locations around the Great Lakes and on their connecting channels.

Effective management of Great Lakes water levels depends largely on the periodic collection and analysis of data from the lakes and public dissemination of this information. The National Ocean Service of the National Oceanic and Atmospheric Administration (NOAA) presently operates 31 water level gages on the Great Lakes and 18 gages on their connecting channels. Historic records for some of these gages go back to 1860. In Canada, the Canadian Hydrographic Service maintains 29 water level gages on the Great Lakes and 27 gages on the St. Lawrence River. Several other agencies operate recording gages at various locations around the Great Lakes system. These agencies include the U.S. Army Corps of Engineers, the New York Power Authority and Ontario Power Generation.



Typical water level gaging station with satellite data relay instrumentation

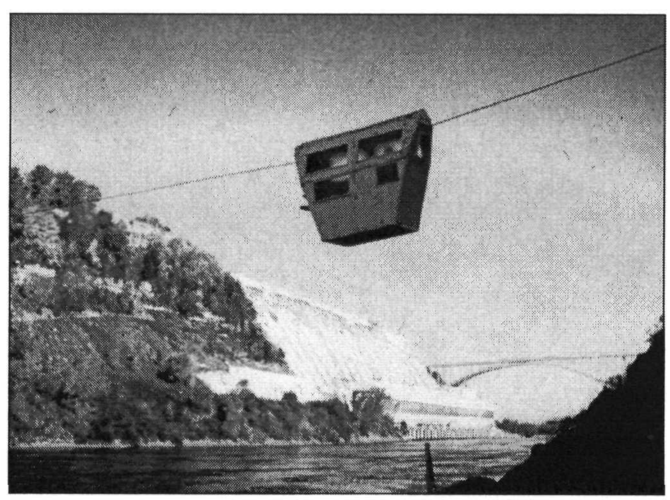
Great Lakes water levels are officially measured from the International Great Lakes Datum 1985 (IGLD 1985). This datum is referenced to sea level, as measured at Rimouski, Quebec, near the mouth of the St. Lawrence River. Because the crust of the earth in the Great Lakes region is continuously rising with respect to sea level, and the rate of movement is not uniform throughout the region, the International Great Lakes Datum must be periodically updated on a 25- to 30-year schedule.

Another datum to which Great Lakes water levels are often referred to is called Chart Datum. All soundings on navigation charts are referenced to this datum. *(For further information on chart datum, see page 32.)*

Measuring outflows

Outflows from the Great Lakes are relatively small (less than 1 percent per year) in comparison with the total volume of water. The rate of flow, or discharge, in a river is determined by measuring the channel depth and width, and the velocity of the flow. These measurements are made at various sections of the river, such as constrictions in the river course. Measurements can be made by boat, from a bridge, or from a cableway strung across the river as in the picture below.

With sufficient measurements of flow over a range of water levels including extreme low and high levels, mathematical relationships can be developed between levels and discharges for various points along the connecting channels and the St. Lawrence River. These stage-discharge equations are essential to the coordination of outflow data, particularly related to hydropower usage of Great Lakes waters.



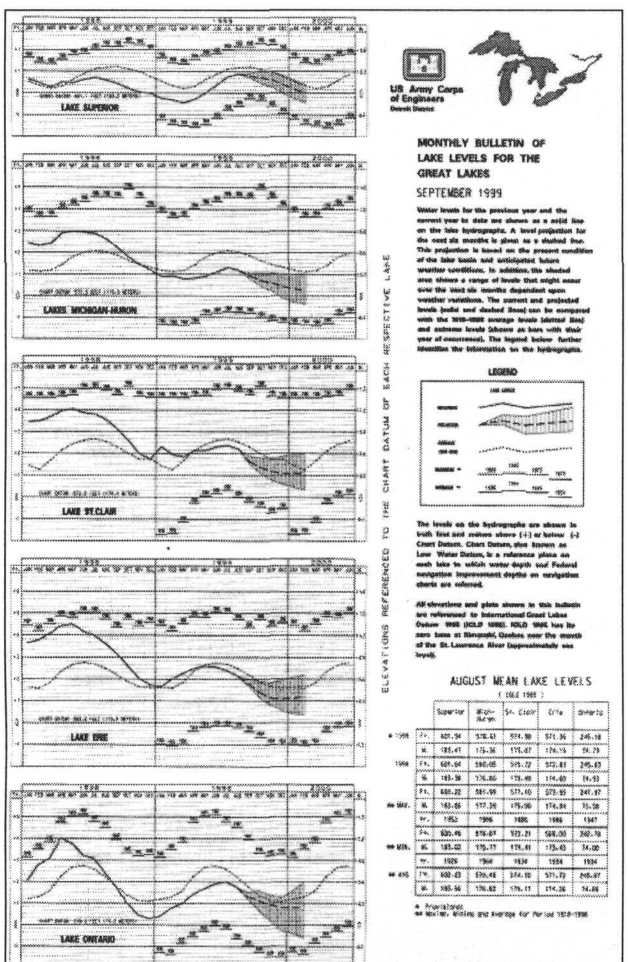
Measuring outflows at the Niagara Cableway across the Niagara Gorge

Water level forecasting

Monthly water level forecasts are available free from the U.S. Army Corps of Engineers and Canadian authorities

Forecasts of water levels for each of the Great Lakes are routinely published by the U.S. and Canadian governments and distributed free to the public. The former U.S. Lake Survey District of the U.S. Army Corps of Engineers began publishing water level forecasts in 1952. Since 1975, the Detroit District of the Corps has continued to produce the forecasts monthly. This product is available on the Internet and by mail in paper form. A weekly forecast update is also produced and is available on the Internet. The Canadian forecasts began in 1973 and currently are generated by Environment Canada and published by the Department of Fisheries and Oceans. These also are published on the Internet and mailed to Canadian recipients. The U.S. and Canadian forecasts are coordinated between agencies to ensure that there is agreement. *(See the Points of Contact and Additional Resources listings on pages 38 and 39.)*

Since it's difficult to predict the weather, it is not surprising that present weather forecasts for one month or beyond are of limited value in forecasting water levels. In practice, water level forecasts depend heavily on looking at recent seasonal fluctuation patterns of water supply. Future water supplies can also be significantly influenced by the condition of the lake and its drainage basin at the time the forecast is made. Key issues associated with this include the wetness of the soils, amount of water stored in the snowpack, depth of the frost in the ground, height of the groundwater table, and/or the temperature of the lake surface.



Monthly Bulletin of Lake Levels for the Great Lakes

With recent scientific advances, particularly in satellite and airborne monitoring systems, ground-based radars and computer modeling techniques, forecasters are gaining valuable knowledge on basin and lake conditions that was not previously available. Sophisticated computer models, in particular, are being created and tested, which can account for daily changes in nearly 25 separate hydrologic variables that can affect water supply to a lake and, therefore, water levels in the future.

There is a limit, however, to how much current basin conditions can influence water supplies to the lakes in the future. For this reason, published water level forecasts normally extend only six months into the future. All forecasts are generated and published showing a probable range of lake levels due to the inherent uncertainty of future weather conditions.

Effects of Lake Level Fluctuations

Stretching more than 9,500 miles, the shores of the Great Lakes are constantly reshaped by the effects of wind, waves and moving water. Shoreline characteristics vary significantly, from flat, low-lying areas susceptible to flooding, to high bluff areas that are often prone to erosion. Erosion is a natural process that occurs during periods of low, average or high water levels. Erosion and flooding can be magnified during periods of high water or storms.

In some areas of high-density development, minor deviations from long-term average levels can produce pronounced economic losses. In less developed areas, these impacts can be modest or negligible.

Natural areas, such as wetlands, have evolved as a result of wide variations in water levels. Reducing these variations can have significant environmental consequences.

Empire Bluffs at Sleeping Bear Dunes National Lakeshore on Lake Michigan

Erosion processes

On the coast, natural forces causing erosion are embodied in waves, currents and wind. Most waves arrive at an angle to the shore. As successive wave fronts advance and retreat they set up a longshore current. As waves break, run up the shore, and return, they carry sedimentary material onshore and offshore. This sedimentary material is called **littoral drift**.

Although erosion is a natural process, its rate and severity can be intensified by human activity.

The energy in the moving water determines the size and amount of the material that will move and how far. The energy in a wave depends on the speed of the wind, its duration and the unobstructed water distance, or fetch, it blows over. Gentle waves move fine sand, whereas storm-generated waves move rocks and boulders. Materials picked up from shoreline areas are deposited wherever the water is slowed down and may be picked up again when the velocity of the water increases.

If erosion is not balanced by **accretion**, the depositing of sediment, the shore will be washed away. Erosion and accretion are two faces of the same process. These processes can occur at extremely slow rates or may occur dramatically in a short time.

Lake Michigan shoreline in Michigan

Natural shores are nourished by material that has been eroded from other areas, becoming part of the littoral drift system. Attempts to reduce erosion by building shore protection structures, or armoring the shoreline in one area, will result in reduced littoral drift available, starving an adjacent area downdrift.

Fluctuating water levels can expose new surfaces to erosion. As seasons change, wind strength and direction also change, altering the path of waves and currents. Where ice forms, it redirects wave energies offshore protecting beaches, but can increase erosion of the lakebed. Ice may also exert tremendous forces that can weaken shore structures.

Gently sloping shores, whether beaches or wetlands, are natural defenses against erosion. The slopes of the land along the edge of the water form a first line of defense called a **berm**, which dissipates the energy of breaking waves. During high water periods, a berm can prevent water from moving inland. Dunes and their vegetation offer protection against storm-driven high water and also provide a reservoir of sand for replenishing the littoral drift and rebuilding beaches.

Although erosion is caused by natural shoreline processes, its rate and severity can be intensified by human activity. Dredging marinas and bulldozing dunes remove natural protection against wind and waves. Pedestrian and vehicle traffic destroy vegetation, degrade dunes, and weaken bluffs and banks. Docks, jetties and other structures interrupt the natural shoreline movement of water and redirect erosive forces, possibly in undesirable directions. Inappropriate building practices in high bluff areas can seriously reduce bluff stability. In particular, drainage patterns from new building construction can cause infiltration of runoff directly into a bluff and can weaken its normal cohesive forces. Wise management of shoreline construction and land uses can significantly reduce economic losses due to erosion.

Habitat diversity

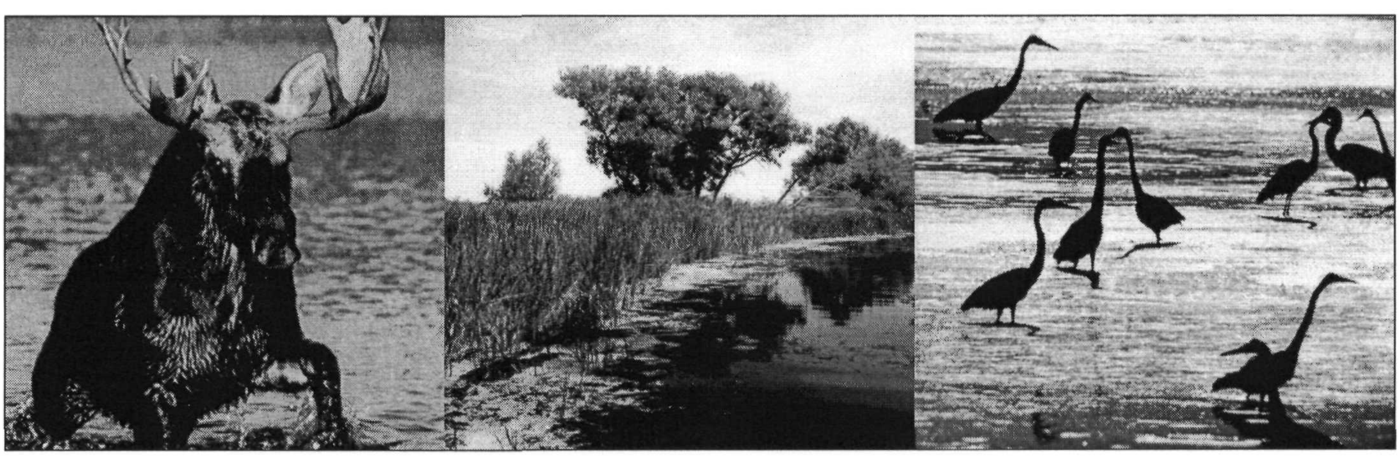
The region's glacial history and the tremendous influence of the lakes themselves create unique conditions that support a wealth of biological diversity, including more than 130 rare species and ecosystems. The Great Lakes are the only lakes of their size in a temperate climate. With the lakes' moderating effect on the climate, the ecosystem is able to provide habitat for a wide variety of species that otherwise might not survive. The Great Lakes - St. Lawrence River ecosystem features sand dunes, coastal marshes, rocky shorelines, lakeplain prairies, savannas, forests, fens, wetlands and other landscapes.

With the lakes' moderating effect on the climate, the ecosystem is able to provide habitat for a wide variety of species that otherwise might not survive.

The place where land and water meet is by far the most diverse and productive part of the Great Lakes - St. Lawrence River ecosystem. This interface includes small wetlands nestled in scattered bays to extensive wetlands such as those along Saginaw Bay on Lake Huron, river-mouth wetlands such as the Kakagon Sloughs of northern Wisconsin and the enormous delta marshes of the St. Clair River. Nearly all species of Great Lakes fish rely on nearshore waters for everything from permanent residence, to migratory pathways, to feeding, nursery grounds and spawning areas.

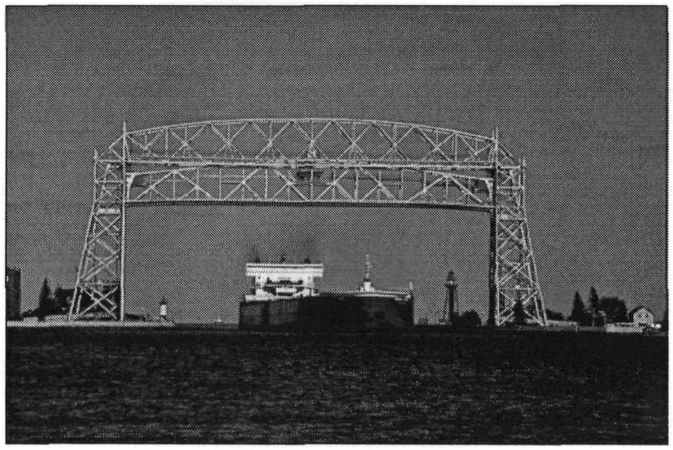
Most common types of wetlands along the shoreline are marshes, where the vegetation can tolerate the large short- and long-term fluctuations in lake levels. In fact, these wetlands are shaped by dynamic lake processes, including waves, currents and changes in water levels. They occur in areas where the erosive forces of ice and wave action are low, allowing the growth of wetland plants. Many wetlands have species successions that are dependent upon water level cycles. Seasonal and long-term water level fluctuations also limit the invasion of woody plants at higher elevations and extensive beds of submersed aquatic plants at lower elevations. Individual wetland species and vegetative communities prefer, and have adapted to, certain water depth ranges, allowing wetlands to be more extensive and more productive than they would be if water levels were stable.

In addition to providing habitat, coastal wetlands play other vital roles. These include protecting nearshore terrestrial ecosystems from erosion by dissipating wave energy, and improving water quality in adjacent aquatic systems through sediment control and absorption of nutrients.



A wealth of biological diversity (left to right): moose in Lake Superior watershed, wetlands along Saginaw Bay on Lake Huron and herons along Lake Ontario shoreline

Commercial shipping and recreational boating

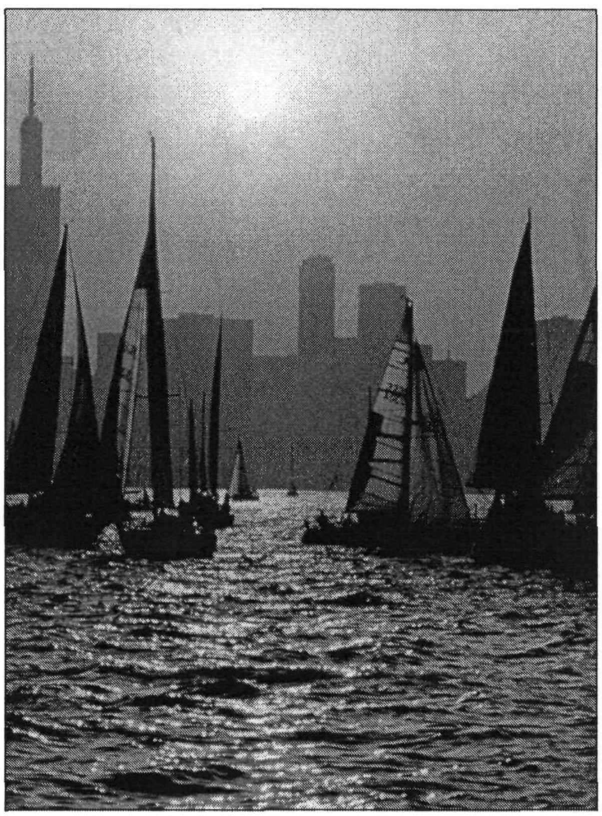


Lift Bridge in Duluth - Superior Harbor on Lake Superior

Water levels have a profound impact upon the economic viability of commercial shipping and recreational boating on the Great Lakes. In the U.S., for example, the federal government maintains 71 deep-draft harbors and 745 miles of dredged channelways to support commercial navigation. Along the nearly 5,800 miles of U.S. Great Lakes and St. Lawrence River shorelines, the government also maintains 65 shallow-draft recreational harbors. The depths to which the harbors and approach channels are dredged have been subject to U.S. congressional authorizations, many of which date back to the 19th century.

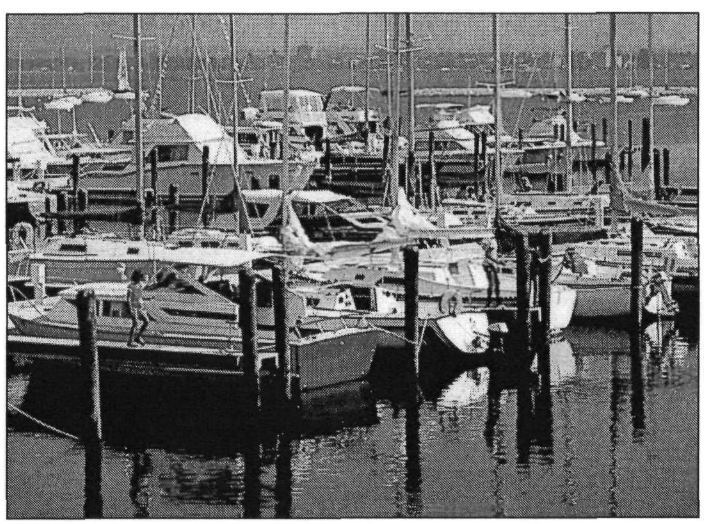
The authorized depth for dredging varies with the type of traffic involved, ranging from a low of 9 feet deep in most recreational boating harbors to 30 foot deep in channels used for ocean-going freighters. Since some harbors serve both commercial and recreational purposes, it is common to see a deeper entrance channel near the harbor mouth for commercial vessels, with progressively shallower depths for recreational interests as one moves upstream.

Boaters should be familiar with and make regular practice of using navigation charts for the waters they expect to navigate. These navigation charts are published in the U.S. by the National Oceanic and Atmospheric Administration (NOAA) and by the Department of Fisheries and Oceans in Canada. All depths or **soundings** on the navigation charts are referenced to **chart datum**, also known as Low Water Datum. Chart datum is different for each lake and is expressed relative to IGLD 1985. Current and forecasted water levels are reported relative to chart datum. With an up-to-date chart and current water level information, navigators can find the depth of water available for transit. For example, if the water level is currently 3 feet above chart datum and the soundings on the chart are 8 feet below chart datum, then there is an actual depth of 11 feet at that location.



Chicago lakefront on Lake Michigan

Boaters should always be aware that the Great Lakes, their connecting channels, and the St. Lawrence River are subject to fluctuating water levels on a short-term basis through storm events, through seasonal changes, and over longer periods due to climatic shifts. Boaters should always use caution and reduce vessel speeds when navigating unfamiliar waters.

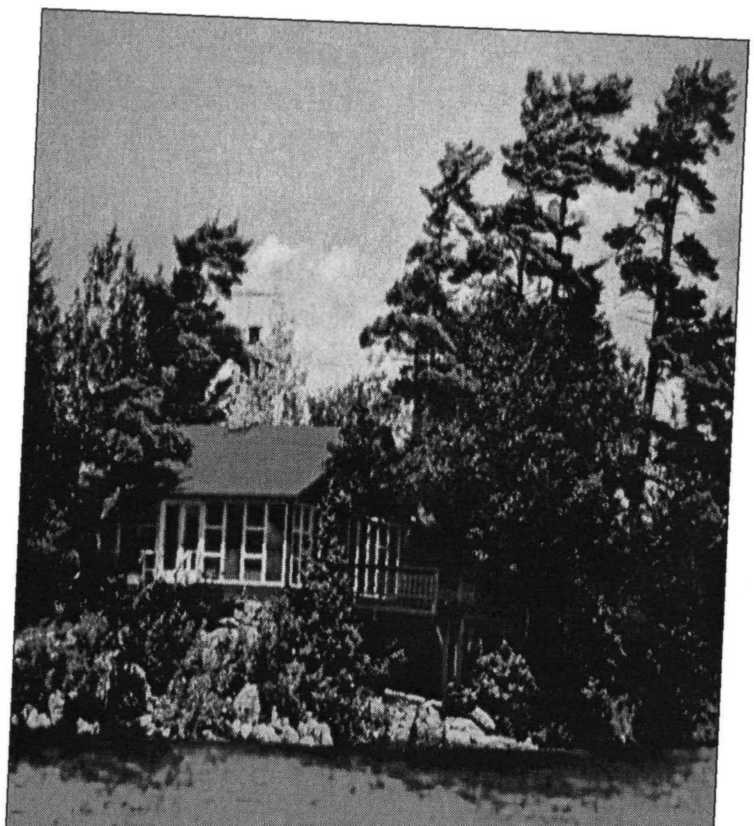


Marina on Lake St. Clair

Living Along the Shoreline

Whether you're a boating enthusiast, business owner, residential property owner, prospective buyer of shoreline property or a member of a coastal community, it's in your best interest to understand the benefits and risks associated with living close to the lakes. A willingness to anticipate and adapt to ever-changing lake levels and their impacts could save you vast amounts of time, money and worry.

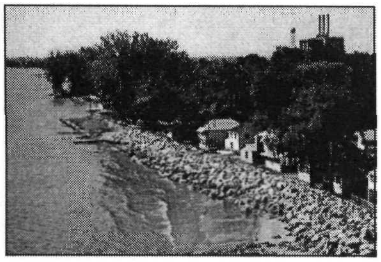
Levels are only one of the complex physical processes exerted upon our Great Lakes shorelines. While individual property owners are powerless to stop these processes, they do have a variety of options for combating erosion and flooding, including structural and nonstructural measures. Careful planning, prudent siting of new construction and awareness of risks are all advised.



Cottage in Thousand Islands area of the St. Lawrence River

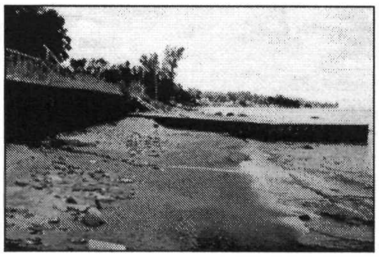
Structural options

A variety of structural options are available to shore property owners to protect and stabilize bluffs and beaches vulnerable to the impacts of lake level fluctuations and storm events. The best structural option depends upon the site characteristics. Professional design consultation is advisable. None of these options, however, are permanent solutions against the continued and relentless forces of nature. Many structures cause erosion downdrift, which can only be mitigated by replacing lost material. In most areas, without mitigation, the relatively thin layer of existing sand is stripped away, exposing underlying clay. The clay is rapidly and irreversibly eroded in a process called **lakebed downcutting.** This process lets larger waves attack closer to shore, increasing the failure rate of coastal structures and bluffs.



Revetment at Luna Pier, Michigan, on Lake Erie

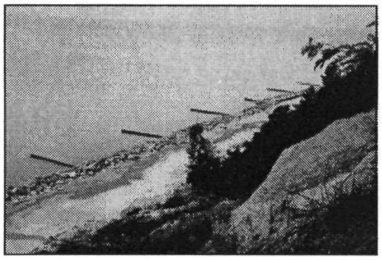
- A **revetment** is a heavy facing, or armor, that protects the slope and adjacent upland from the erosive effects of wave scour. Revetments, which are best suited for gentle to moderate slopes, are comprised of three layers: armor, filter layers and toe protection. Typical armor materials, which include stone and gabions (wire baskets filled with stone) are designed to disperse wave energy that would otherwise impact the shoreline. The filter layer, comprised of graded stone, provides a stable foundation for the armor and permits groundwater drainage. Toe protection, which prevents settlement of the revetment and stabilizes the revetment's lakeward edge, is an extension of the armor material. Private revetments can temporarily protect some types of bluffs, but will likely cause erosion in downdrift areas by starving these shorelines of natural sand supply. Any beach present prior to construction will typically be lost.



A bulkhead and companion breakwater in Sanilac County, Michigan, on Lake Huron

- **Bulkheads (or seawalls)** are retaining walls that prevent soil from eroding into a water body due to wave action. Construction can vary from thin structures that penetrate the ground like sheet piling to massive structures that rest on the surface such as poured concrete structures or stone-filled timber cribs. Bulkheads protect only the land immediately behind them by retaining soil at the toe of a bluff; they do not ensure the overall stability of the bluff and do not offer protection to adjacent areas. Bulkheads may worsen erosion downdrift in the same manner as revetments. In the long term, erosion of the lakebed will worsen immediately in front of the bulkhead.

- **Breakwaters** are offshore structures typically placed parallel to the area of shoreline to be protected. Constructed of stone, steel, wood or concrete, breakwaters block and disperse wave energy, which can minimize shore damage. Breakwaters help build a beach in their protected shadow, but can worsen erosion downdrift by blocking transport of sediments along the shore.



Groin and revetment system near St. Joseph, Michigan, on Lake Michigan

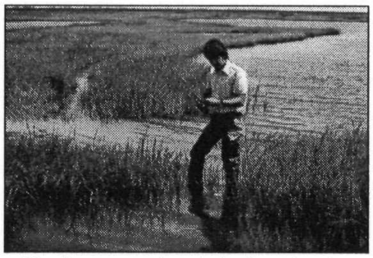
- **Groins** are structures that are placed perpendicular to shore and extend out into the water. Used either singly or in a series as part of a **groin field**, they trap and accumulate sand on the updrift side of the groin. Provided enough sand moves naturally along the shoreline, groins can be effective in building up beaches. Groins are typically constructed of the same materials used for revetments and breakwaters. Groins will aggravate erosion problems downdrift by blocking sediment transport along the shore.

Nonstructural options

Nonstructural options for bluff stabilization and shoreline protection offer the shore property owner a variety of measures that have a strong land-use management emphasis.


Beach grasses along Lake Michigan

- **Revegetation** is a planting program to establish desired species for bluff and beach stabilization, which is among the least expensive of all protection measures. A variety of groundcover, including species of grasses, sedges and bulrushes, are effective at trapping sand particles and stabilizing beach and bluff areas. Upland species of grasses, shrubs and trees are effective in higher beach elevations. While useful for slope stabilization and erosion control, revegetation alone is not effective under conditions of heavy wave action in high bluff environments. Conversely, in areas of shallow relief, extensive coastal wetlands can effectively eliminate wave forces on adjacent beaches.

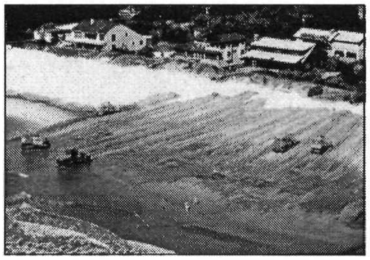

Marsh grasses along Lake Superior shores

- **Bluff drainage** is a measure that addresses seepage problems common to clay or composite bluffs. Seepage contributes to bluff instability when upper layers are saturated, slough off, and are ultimately carried away by wave action. Open joint tile drains, laid in a trench set back from the top of the bluff and back-filled with crushed stone, can help resolve shallow (less than 6 feet deep) groundwater drainage problems. Vertical wells with sump pumps can be used for deeper drainage problems.

- **Slope re-grading** is a measure by which unstable bluffs can be re-graded to a more gradual or stable slope. Coupled with revegetation, this measure can be effective in reducing the rate of erosion and bluff recession, assuming the lakebed has not been irreversibly downcut.


Sandy beach along southern Lake Superior

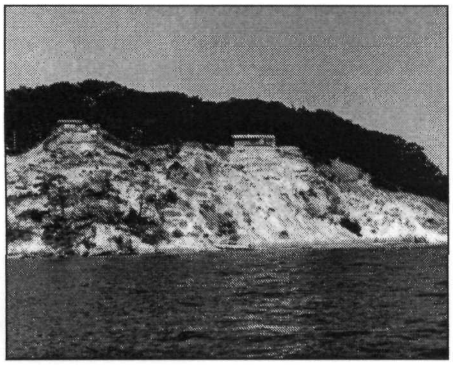
- **Beach nourishment** is the placing of quantities of sand, gravel, or stone on the shoreline by overland hauling or nearshore pumping from barges. The deposits serve as a buffer zone that slows erosion. Wave action carries the material offshore, where it can form sand bars that may cause waves to break farther from the beach. To extend its life span, beach nourishment often requires using larger and heavier deposits than would naturally occur, causing a change in beach characteristics. The useful life of a nourished beach depends upon the size and quantity of materials placed on the beach as well as the frequency and severity of storms that erode the deposits.


Beach nourishment along Lake Michigan

- **Relocation** is the removal of structures vulnerable to damage from storm-induced flooding and erosion. This option recognizes that erosion and associated bluff recession is a natural process that, even with installation of structural protection, is difficult to stop entirely. Provided that the shoreline property is of sufficient size and depth to accommodate relocation of the structure(s), this option is often more cost-effective and reliable in the long-term than most structural options.

Community measures

Additional nonstructural options entail the development and implementation of land-use and shoreline management measures that can prevent new damage from occurring. Many such techniques lend themselves to public policy actions, such as local ordinances, but also can be implemented by the individual property owner on a voluntary basis. These include:


High bluff along Lake Michigan shoreline

- erosion setbacks with minimum requirements for both movable and permanent structures;
- flood setbacks and elevation requirements for new structures;
- requirements/guidelines for shoreline alteration to ensure that updrift and downdrift impacts are considered and mitigated for;
- real estate disclosure requirements to ensure that a prospective buyer is fully informed as to whether the property is within a mapped or known flood or erosion hazard area; and
- adoption of hazard insurance programs that provide for mapping of hazard zones, establishing setbacks for new construction, and denying subsidized insurance for new construction or major renovations within the flood or erosion hazard area.

An additional nonstructural option available to both public and nongovernmental agencies and organizations is the implementation of conservation practices including the purchase of developed and undeveloped property in hazard areas for recreational use, habitat enhancement or other purposes.

Selecting the best options

Stakeholders in the Great Lakes need to be aware of long-term water level history; knowledge of the past can help to minimize future losses.

Lake level fluctuations, storm events and related natural processes continuously reshape the coastal zone through flooding and erosion. These processes are an integral part of the ecosystem; it is neither economically feasible nor environmentally desirable to severely limit these processes.

Shoreline property owners should be cognizant of long-term lake level history so they will not be surprised by what happens in the future. While various private protective structures can be effective in temporarily protecting shorelines and associated buildings, none will be permanent. Ownership of shore property and structures has many benefits, but does require a thorough understanding and acceptance of the risks involved.

"Let the buyer beware" is sound advice to any prospective shore property owner. Every aspect of the property's history should be investigated thoroughly, particularly past flooding or erosion patterns and structural and nonstructural shoreline protection measures that either need to be maintained or possibly installed on the property. Selecting and implementing one or more management measures will be one of the most significant decisions shoreline communities and their citizens can make. Careful planning, including assistance from public agencies and reputable professionals, is advised.

States and Provinces

Illinois

Illinois Dept. of Natural Resources
Division of Water Resources
310 South Michigan Avenue, Room 1606
Chicago, IL 60604
Phone: 312-793-3123
Fax: 312-793-5968
http://dnr.state.il.us/waterresources/

Illinois State Emergency Management Agency
110 East Adams
Springfield, IL 62701-1109
Phone: 217/782-2760
Fax: 217/782-2589
http://www.state.il.us/iema/

Indiana

Indiana Dept. of Natural Resources
Division of Water
402 West Washington, Room W264
Indianapolis, IN 46241
Phone: 317-232-4160
Fax: 317-233-4579
http://www.state.in.us/dnr/water/

Indiana State Emergency Management Agency
Recovery Division
402 West Washington, Room W046
Indianapolis, IN 46204
Phone: 317-233-4626
Fax: 317-232-4987
http://www.state.in.us/sema/

Illinois-Indiana Sea Grant College Program
Purdue University
1200 Forest Products Building
West Lafayette, IN 47907-1200
Phone: 765-494-3573
http://ag.ansc.purdue.edu/il-in-sg/

Michigan

Michigan Department of Environmental Quality
Land and Water Management Division
P.O. Box 30458
Lansing, MI 48909-7958
Phone: 517-373-1170
Fax: 517-373-9965
http://www.deq.state.mi.us

Michigan State Police
Emergency Management Division
4000 Collins Road
P.O. Box 30636
Lansing, MI 48909-8136
Phone: 517-336-6198
Fax: 517-333-4987
http://www.msp.state.mi.us

Michigan Sea Grant College Program
2200 Bonisteel Boulevard
Ann Arbor, MI 48109-2099
Phone: 734-763-1437
http://www.engin.umich.edu/seagrant/

Minnesota

Minnesota Department of Natural Resources
Division of Water
DNR Building, 3rd Floor
500 Lafayette Road
St. Paul, MN 55155
Phone: 651-296-4800
Fax: 651-296-0445
http://www.dnr.state.mn.us/waters/

Minnesota Board of Water & Soil Resources
One West Water Street, Suite 200
St. Paul, MN 55107
Phone: 612-296-3767
Fax: 612-297-5615
http://www.bwsr.state.mn.us/

University of Minnesota Sea Grant Program
2305 East 5th Street
Duluth, MN 55812-1445
Phone: 218-726-8715
Fax: 218-726-6556
http://www.d.umn.edu/seagr/

New York

New York State Department of Environmental Conservation
Bureau of Flood Protection
50 Wolf Road, Room 388
Albany, NY 12233
Phone 518-457-3157
Fax 518-485-7786
http://www.dec.state.ny.us

New York State Emergency Management Office
1220 Washington Avenue
Building 22 - Suite 101
Albany, NY 12226-2251
Phone: 518-485-1797
Fax: 518-457-7528
http://www.nysemo.state.ny.us

New York Sea Grant Institute
115 Nassau Hall
SUNY at Stony Brook
Stony Brook, NY 11794-5001
Phone: 516-632-6905
Fax: 516-632-6917
http://www.seagrant.sunysb.edu/

Ohio

Ohio Dept. of Natural Resources

Ohio Coastal Management Program
Div. of Real Estate & Land Management
Fountain Square, Bldg C, 4th Floor
Columbus, OH 43224
Phone: 888-644-6267
or 614-265-6384
Fax: 614-267-4764
http://www.dnr.state.oh.us/odnr/relm/

Division of Water
Fountain Square, Building E
Columbus, OH 43224
Phone: 614-265-6717
Fax: 614-447-9503
http://www.dnr.state.oh.us/odnr/water/

Division of Geological Survey
P.O. Box 650
Sandusky, OH 44870
Phone: 419-626-4296
Fax: 419-626-8767
http://www.dnr.state.oh.us/odnr/geo_survey/

Division of Engineering
Fountain Square, Bldg F, 3rd Floor
Columbus, OH 43224
Phone: 614-265-6948
Fax: 614-262-2197
http://www.dnr.state.oh.us/odnr/engineering/

Ohio Sea Grant College Program
1314 Kinnear Road
Columbus, OH 43212-1194
Phone: 614-292-8949
Fax: 614-292-4364
http://www.sg.ohio-state.edu/

Ohio Emergency Management Agency
2855 West Dublin-Granville Road
Columbus, OH 43235-2206
Phone: 614-889-7150
Fax: 614-889-7183
http://www.state.oh.us/odps/division/ema/

Pennsylvania

Pennsylvania Department of Environmental Protection

Bureau of Watershed Conservation
Watershed Support Division
Coastal Zone Management, 10th Floor
Rachel Carson State Office Building
P.O. Box 8555
Harrisburg, PA 17105-8555
Phone: 717-787-5259
Fax: 717-787-9549
http://www.dep.state.pa.us

Coastal Zone Management Program
Northwest Regional Office
230 Chestnut Street
Meadville, PA 16335-3481
Phone: 814-332-6942
Fax: 814-332-6121
http://www.dep.state.pa.us

Pennsylvania Emergency Management Agency
P.O. Box 3321
Harrisburg, PA 17105-3321
Phone: 717-651-2009
Fax: 717-651-2040
http://www.pema.state.pa.us

Pennsylvania Sea Grant Project
Penn State - Erie
5091 Station Road
Erie, PA 16563-0101
Phone: 814-898-6420
Fax: 814-898-6462
http://www.pserie.psu.edu/seagrant/

Wisconsin

Wisconsin Dept. of Natural Resources
Bureau of Watershed Management
P.O. Box 7921
Madison, WI 53707
Phone: 608-267-7694
Fax: 608-267-7664
http://www.dnr.state.wi.us

Wisconsin Dept. of Administration
Coastal Management Program
P.O. Box 7868
Madison, WI 53707
Phone: 608-261-6349
Fax: 608-267-6931
http://www.doa.state.wi.us/deir/coastal.htm

University of WI Sea Grant Institute
University of Wisconsin - Madison
1975 Willow Drive
Madison, WI 53706-1103
Phone: 608-262-0905
Fax: 608-262-0591
http://www.seagrant.wisc.edu/

Ontario

Ontario Ministry of the Environment
Water Policy Branch
40 St. Clair Avenue West, 12th & 14th Floors
Toronto, ON M4V 1M2
Phone: 416-314-3923
Fax: 416-314-4128
http://www.ene.gov.on.ca/envision/org/iepd.htm

Ontario Ministry of Natural Resources
Peterborough Regional Office
4th Floor, 300 Water St., P.O. Box 7000
Peterborough, ON K9J 8M5
Phone: 705-755-2500
Fax: 705-755-1267
http://www.mnr.gov.on.ca/mnr/

U.S. federal agencies

U.S. Army Corps of Engineers
Great Lakes Regional Office
111 North Canal Street, Suite 1200
Chicago, IL 60606
Phone: 312-353-6310
Fax: 312-353-5233
http://www.lrd.usace.army.mil/gl/gl.htm
Buffalo District
1776 Niagara Street
Buffalo, NY 14207
Phone: 716-879-4104
http://www.lrb.usace.army.mil
Chicago District
111 North Canal Street
Chicago, IL 60606-7206
Phone: 312-353-6400
http://www.usace.army.mil/lrc
Detroit District
477 Michigan Avenue
Detroit, MI 48226
Phone: 313-226-6440
Fax: 313-226-2398
http://www.lre.usace.army.mil

U.S. Coast Guard - Ninth District
Marine Safety Division, 1240 East Ninth St.
Cleveland, OH 44199-2060
Phone: 216-902-6045
Fax: 216-902-6059
http://www.uscg.mil/d9/uscgd9.html

U.S. Department of Agriculture
Natural Resources Conservation Service (NRCS)
Midwest Regional Office
2820 Walton Commons W., Suite 123
Madison, WI 53716
Phone: 608-224-3001
Fax: 608-224-3010
http://www.mw.nrcs.usda.gov/
Farm Service Agency (FSA)
1400 Independence Avenue, S.W.
3086 SAG
Washington, DC 20250
Phone: 202-720-3467
Fax: 202-720-9105
http://www.fsa.usda.gov

U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
Great Lakes Environmental Research Laboratory (GLERL)
2205 Commonwealth Boulevard
Ann Arbor, MI 48105-1593
Phone: 734-741-2235
Fax: 734-741-2003
http://www.glerl.noaa.gov/

U.S. Department of the Interior
Fish & Wildlife Service
Great Lakes-Big Rivers Region
1 Federal Drive, BHW Federal Building
Fort Snelling, MN 55111
Phone: 612-713-5360
http://www.fws.gov/r3pao/
U.S. Geological Survey
Biological Resources Division
Great Lakes Science Center
1451 Green Road
Ann Arbor, MI 48105
Phone: 734-994-3331
Fax: 734-994-8780
http://www.glsc.usgs.gov/

Federal Emergency Management Agency (FEMA)
Region II
26 Federal Plaza
Suite 1337
New York, NY 10278
Phone: 212-225-7209
Fax: 212-225-7281
http://www.fema.gov/reg-ii/regii.htm
Region III
One Independance Mall, Sixth Floor
615 Chestnut Street
Philadelphia, PA 19106-4404
Phone: 215-931-5608
Fax: 215-931-5621
http://www.fema.gov/reg-iii/regiii.htm
Region V
536 South Clark Street, 6th Floor
Chicago, IL 60605-1521
Phone: 312-408-5501/5503
Fax: 312-408-5234
http://www.fema.gov/reg-v/regv.htm

U.S. Environmental Protection Agency
Great Lakes National Program Office
77 West Jackson Boulevard
Chicago, IL 60604
Phone: 312-353-2117
Fax: 312-353-2018
http://www.epa.gov/glnpo
U.S. EPA Region 2
290 Broadway
New York, NY 10007
Phone: 212-637-3000
http://www.epa.gov/region2/
U.S. EPA Region 3
1650 Arch Street
Philadelphia, PA 19103-2029
Phone: 215-814-2300
http://www.epa.gov/region3/
U.S. EPA Region 5
77 West Jackson Boulevard
Chicago, IL 60604
Phone: 312-353-2000
http://www.epa.gov/region5/water/

Canadian federal agencies

Environment Canada
Great Lakes Water Level Communication Centre
867 Lakeshore Road
Burlington, ON L7R 4A6
Phone: 905-336-4580
Fax: 905-336-8901

Great Lakes - St. Lawrence Regulation Office
111 Water Street East
Cornwall, ON K6H 6S2
Phone: 613-938-5725
Fax: 613-937-1302

Department of Fisheries and Oceans
Canadian Hydrographic Service
867 Lakeshore Road, P.O. Box 5050
Burlington, ON L7R 4A6
Phone: 877-247-5465
Fax: 905-336-8916
http://chswww.bur.dfo.ca/danp/

Binational agencies

Great Lakes Commission
Argus II Building, 400 Fourth Street
Ann Arbor, MI 48103-4816
Phone: 734-665-9135
Fax: 734-665-4370
http://www.glc.org

Great Lakes Fishery Commission
2100 Commonwealth Blvd., Suite 209
Ann Arbor, MI 48105
Phone: 734-662-3209
Fax: 734-741-2010
http://www.glfc.org

International Joint Commission
http://www.ijc.org
U.S. Section
1250 23rd Street N.W., Suite 100
Washington, DC 20440
Phone: 202-736-9000
Fax: 202-736-9015
Canadian Section
100 Metcalfe Street, 18th Floor
Ottawa, ON K1P 5M1
Phone: 613-995-2984
Fax: 613-993-5583
Great Lakes Regional Office
100 Ouellette Ave. 8th Floor
Windsor, ON N9A 6T3
Phone: 313-226-2170
Fax: 519-257-6740

Additional Resources

Online and video resources

Great Lakes - St. Lawrence River Hydrology, Great Lakes Information Network (GLIN):
http://www.great-lakes.net/envt/water/hydro.html
Includes links to current, forecasted and historical data on water levels, water flows, and weather and climate. Also features overviews of hydrology concepts written by experts in the Great Lakes region; and comprehensive lists of agencies and organizations, datums, laws, newsletters and related FAQs. Created under the guidance of the binational Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data and the U.S. Army Corps of Engineers, Detroit District.

Great Lakes Hydraulics & Hydrology Home Page, U.S. Army Corps of Engineers/Detroit District:
http://huron.lre.usace.army.mil/hmpghh.html
Includes current and forecasted water levels, key water level updates and newsletters, and multi-media resources.

Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data:
http://huron.lre.usace.army.mil/coord/cchome.html
Includes information and data coordinated between the U.S. and Canada used for the management of Great Lakes resources.

Evaluating Your Coastal Property (Video, VHS format), University of Wisconsin Sea Grant Institute; advises on shoreline property construction and building placement.

Living on the Edge (Video, VHS format), U.S. Army Corps of Engineers, Detroit District; explores the many influences on levels and flows of the Great Lakes system; ***preview at http://huron.lre.usace.army.mil/levels/vidpromo.html***

The ADVISOR, Great Lakes Commission: ***http://www.glc.org/docs/advisor/advisor.html***
Bimonthly newsletter of the GLC, providing regular updates on policy positions and programs, regional events and binational Great Lakes issues.

Focus, International Joint Commission: ***http://www.ijc.org/focus***
Quarterly newsletter of the IJC contains regular updates on Commission and Board activities and emerging Great Lakes water quality and quantity issues.

LEVEL News, Environment Canada, Great Lakes Water Level Communication Centre:
http://www.cciw.ca/glimr/data/level-news/intro.html
Includes monthly updates on weather conditions, levels and flows, public meetings and Great Lakes facts.

For further reading

An Introduction to Michigan's Water Resources, Institute for Water Resources, Michigan State University

Beaches are Shore Protection, Ohio Sea Grant College Program

Bluff Slumping & Stability: A Consumer's Guide, Michigan Sea Grant College Program

Coastal Erosion and the Residential Property Market, Ohio Sea Grant College Program

Coastal Processes Manual, 2nd Edition, University of Wisconsin Sea Grant Institute

Erosion Abatement Tips, Assessment and Assistance, Ohio Sea Grant College Program

Great Lakes-St. Lawrence River Regulation: What it Means and How it Works, Environment Canada and U.S. Army Corps of Engineers, North Central Division

Great Lakes Water Levels, Environment Canada

Guide to Lake Erie Bluff Stabilization, Ohio Sea Grant College Program

How to Use Fill Material in Stabilizing Shoreline Bluffs or Banks, University of Wisconsin Sea Grant Institute

Identify Your Shoreline Erosion Problems (Fact Sheet), Ohio Sea Grant College Program

Low Cost Shore Protection...a Property Owner's Guide, U.S. Army Corps of Engineers

Methods of Alleviating the Adverse Consequences of Fluctuating Water Levels in the Great Lakes-St. Lawrence River Basin, A Report to the Governments of Canada and the United States, 1993, International Joint Commission

Questions to Ask Before You Buy Great Lakes Shoreline Property (Fact Sheet), Ohio Sea Grant College Program

Shoreline Erosion: Questions and Answers, Revised 1986, Michigan Sea Grant College Program

Vegetation and its Role in Reducing Great Lakes Shoreline Erosion, Michigan Sea Grant College Program

Exhibit C

Rates and Processes of Bluff Recession Along the Lake Michigan Shoreline in Illinois, Randall W. Jibson and Jackson K. Odum, U.S. Geological Survey, Journal of Great Lakes Research, (1994) Conclusions

1. Parallel retreat - notwithstanding changes [illegible] causing High/low
2. Shore protective works little effect
3. Process not governed. as suspected

J. Great Lakes Res. 20(1):135–152
Internat. Assoc. Great Lakes Res., 1994

Rates and Processes of Bluff Recession Along the Lake Michigan Shoreline in Illinois

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Denver, Colorado 80225

John-Mark Staude

U.S. Geological Survey
210 East Seventh Street
Tucson, Arizona 85705

ABSTRACT. *We examined bluffs along 30 km of the Lake Michigan shoreline from Wilmette to Waukegan, Illinois, to measure amounts and variation in retreat rates and to determine what factors control rates and processes of retreat. The predominant bluff-retreat process is shallow- to intermediate-depth translational landsliding triggered by heavy rainfall and wave erosion at the base of the bluff; rotational slumping and shallow creep and earth flow also are common. Using historical maps and airphotos, we measured amounts of bluff-top retreat at 300 locations. For two time periods, 1872-1937 and 1937-1987, rates of retreat vary from 10 to 75 cm/yr between discrete segments of bluffs (defined by lithology) and between time periods for a given bluff segment. The average retreat rates for the entire area, however, do not vary significantly between the two time periods and are approximately 20-25 cm/yr. Long-term average and short-term extreme lake levels and precipitation also do not vary significantly between the two periods, and thus local temporal variations in retreat rate cannot be attributed to these factors. Shore protection built to date may have altered the spatial distribution of retreat rates in the area but has had little overall effect on the average regional retreat rates. The temporally constant regional retreat rates and the regular form of the local shoreline indicate that a long-term uniform rate of retreat prevails and that local variations in rates balance out through time to produce long-term parallel (in map view) bluff retreat in the area. This parallel bluff retreat probably is controlled primarily by the uniform retreat rate of the lithologically homogeneous shoreface in front of the bluff.*

INDEX WORDS: *Lake Michigan, Illinois, bluff retreat, shoreline processes, landslide, coastal erosion.*

INTRODUCTION

Record high levels of Lake Michigan in the mid-1980s created a period of increased shoreline erosion in the developed areas from Chicago to Waukegan, Illinois (Fig. 1). Much of this shoreline consists of steep bluffs that locally have responded to brief periods of high lake levels by retreating at accelerated rates. The recent period of increased retreat rates provoked concerns about the safety of structures along the shoreline. We studied bluff retreat in this area to determine what factors influence the processes and rates of bluff retreat, to measure and interpret spatial and temporal changes in those rates and processes, and to provide information that could be used by public officials, planners, and engineers.

In this paper, we address both the scientific and practical aspects of coastal bluff recession in Illinois. We begin by describing the physical setting of the bluffs; we then discuss the predominant processes of bluff retreat in the area. Next we describe a method for measuring bluff retreat; document the amount and rate of bluff retreat from 1872 to 1987 at 100-m intervals along the 30 km of shoreline studied; and measure rates of retreat for two subdivisions of this period, 1872-1937 and

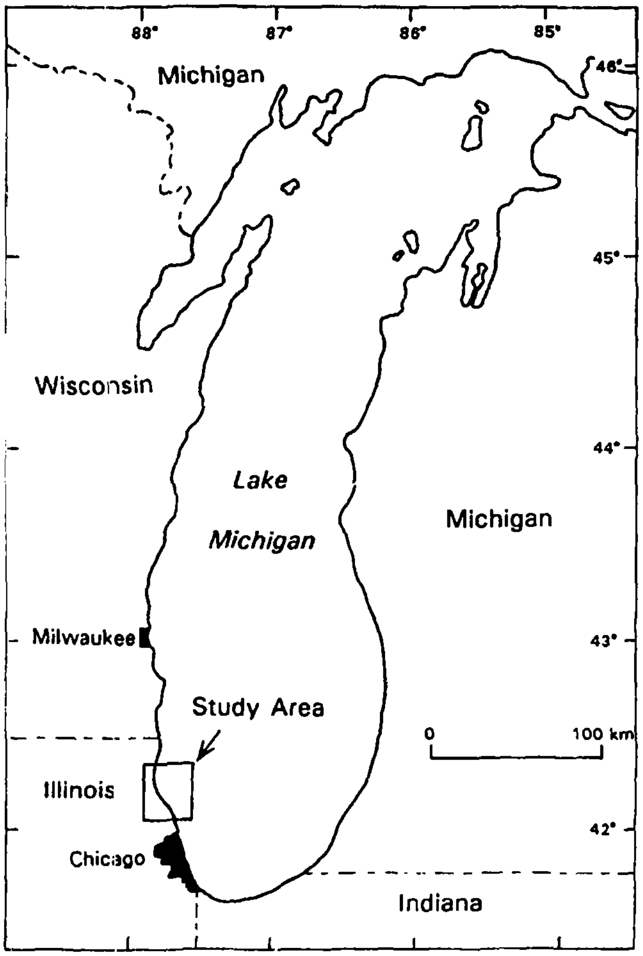

FIG. 1. Location map. Study area shown in Figure 2.

1937-1987, to measure temporal changes in retreat rates. We then relate observed temporal and spatial variations in retreat rates to temporal changes in lake level and precipitation and to spatial differences in bluff height, bluff lithology, and construction of shore-protective works to determine how these factors influence bluff retreat rates. Finally, we estimate the annual volume of sand and gravel, silt, and clay contributed to the littoral sediment transport system by bluff retreat.

GEOLOGY AND MORPHOLOGY OF THE BLUFFS

The bluffs consist of late Wisconsin glacial deposits, primarily till of the Lake Border morainic system (Willman 1971), which is a morphostratigraphic unit of the Wadsworth Till Member of the Wedron Formation (Frye *et al.* 1969, Willman and Frye 1970). Although Clark and Rudloff (1990) show that the Wadsworth Till Member includes a variety of glaciolacustrine deposits as well as till, we designate these deposits as till for brevity. Lacustrine sediment of the Equality Formation (Willman and Frye 1970) deposited in Glacial Lake Chicago (Clark and Rudloff 1990) locally overlies till of the Lake Border moraine system. From Waukegan to the Great Lakes Naval Training Center (Fig. 2), the bluffs are composed of silty clay till of the Zion City moraine interbedded with glaciolacustrine silt, sand, and gravel. From the Naval Training Center to Lake Forest, the bluffs consist of lacustrine silts, sands, and gravels overlying 3-4 m of till exposed at the base of the bluff. The Highland Park moraine, which is lithologically and geomorphically similar to the Zion City moraine, is exposed from Lake Forest to Winnetka. Between Winnetka and Wilmette, the bluff is only 5-10 m high and consists of interbedded lacustrine silt and gravel overlying about 2 m of till exposed at the base of the bluff. Figure 3 shows idealized cross sections of bluffs consisting of (A) till and (B) lacustrine sediment overlying till. Hereafter, bluffs composed of these two sediment types will be referred to as till bluffs and lacustrine bluffs, respectively.

The bluffs can be separated into two morphologically distinct reaches, whose boundary is defined by an abrupt doubling of the bluff height (Fig. 4) at the terminus of the Highland Park moraine (Fig. 2). The bluff formed by the southern outcrop of lacustrine deposits between Wilmette and Winnetka (segments 1-52), which we refer to as the low bluff, averages 8 m in height and has 15°-25° slopes. The bluff from Winnetka to Waukegan (segments 53-300), which we refer to as the high bluff, averages 19 m in height and has slopes from 25° to almost vertical. Figure 4 shows that the height of the till bluffs is highly variable, whereas the lacustrine bluffs have more consistent heights. The entire bluff supports a thick cover of deciduous trees and associated underbrush. Perched ground water commonly seeps from the bluff face along contacts between layers of contrasting permeability. Almost the entire length of the bluff has some sort of engineered shore protection, but type and quality vary substantially.

Land use along the bluffs is primarily moderate-density housing. Large, single-family homes on medium to large, well-landscaped lots are present along most of the bluff; parks, golf courses, and

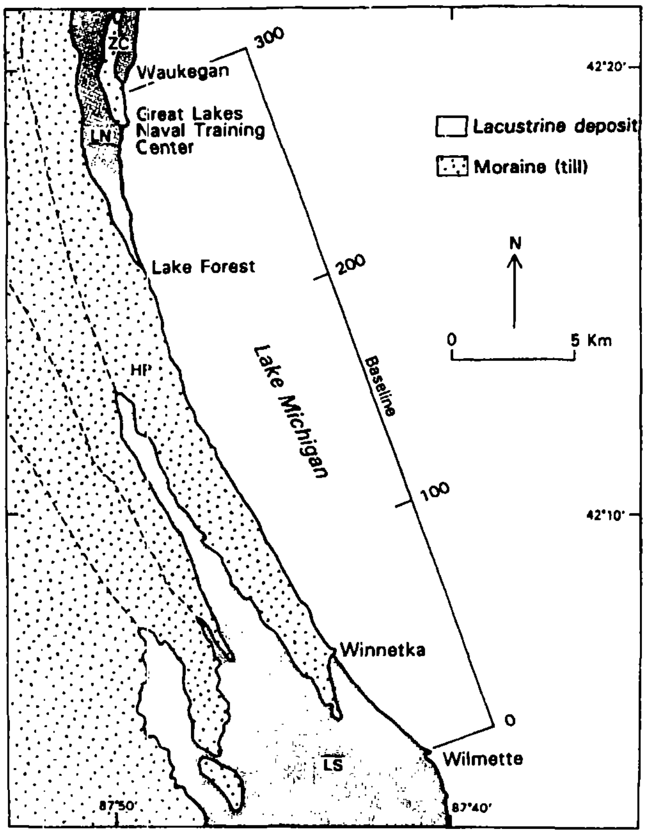

FIG. 2. Map showing the surficial geology of the study area (generalized from Willman and Lineback 1970). Baseline shows bluff segment numbers. Geologic units: LN, northern outcrop of lacustrine deposits; LS, southern outcrop of lacustrine deposits; HP, Highland Park moraine; ZC, Zion City moraine. Dashed contacts separate distinct moraines.

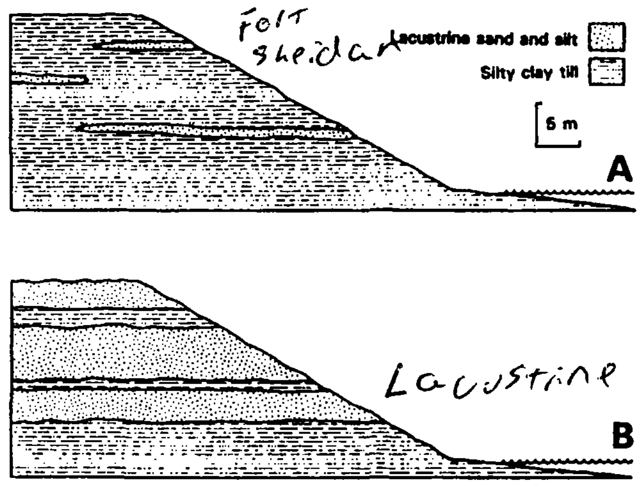

FIG. 3. Typical cross sections of bluffs in the study area. A, bluff in silty clay till; B, bluff in lacustrine sand and silt overlying till.

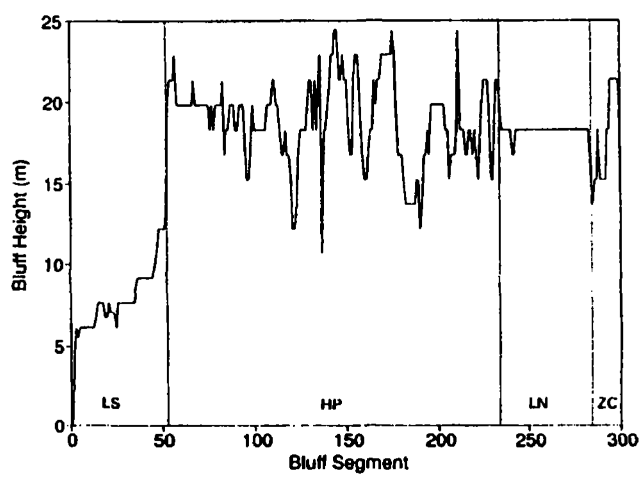

FIG. 4. Graph showing variation in bluff height in the study area. Vertical dashed lines show locations of contacts between till and lacustrine bluffs; abbreviations as in Figure 2.

cemeteries also are present. The primary effect of land-use variation along the bluffs would be on surface and ground water: roads and structures decrease ground-water infiltration (which would reduce the likelihood of landsliding) and increase surface runoff (which would enhance surface erosion). Because development and land use along the entire bluff are fairly uniform, the effect of land-use variation need not be considered in this study.

PROCESSES OF BLUFF RETREAT

Retreat of shoreline bluffs (either lacustrine or oceanic) can result from a variety of processes that operate at different rates and that respond to different triggering mechanisms. For example, wave erosion is a primary cause of bluff retreat, and brief, intense storms that generate large wave surges can trigger very large amounts of bluff retreat in a matter of a few hours or days. Longer term basin-wide or eustatic increases in water level also can increase long-term rates of bluff erosion and recession by submerging beaches and exposing bluffs more directly to wave action (Vallejo and Degroot 1988). Surface erosion from runoff can contribute to bluff recession: runoff from normal rainfall produces what might be considered a background rate of surface erosion, and less common major rainstorms may trigger brief episodes of surface erosion that far exceed the background rate. Landslides along the bluffs likewise contribute to bluff retreat, and such slides can be triggered by long-term changes in ground-water conditions, brief periods of intense rainfall, rapid snowmelt, and wave erosion that undermines and oversteepens the base of the bluff.

The predominant mechanism of bluff retreat in the study area appears to be shallow- to intermediate-depth (0-5 m) landsliding triggered by wave erosion at the toe of the bluff and by seasonal rainfall. Several studies have characterized this process in detail for bluffs in Wisconsin, immediately north of our study area (Edil and Vallejo 1977, 1980; Edil and Haas 1980; Edil 1982; Bosscher *et al.* 1988; Edil and Bosscher 1988; Vallejo and Degroot 1988). The conclusions of these studies can be summarized as follows: (1) shallow- and intermediate-depth translational and rotational slides predominate, (2) deep rotational slides that involve the total bluff (from top to toe) are rare or nonexistent, (3) shallow creep and flow of surficial layers parallel to the bluff face is common, (4) wave erosion of the toe of the bluff triggers slope instability and influences slope morphology, and (5) landslides are most active in response to heavy spring rainfall. Our observations of bluff retreat in Illinois are consistent with these conclusions.

Most slope movement in the study area involves complex failure geometries where the slip surfaces at the head and toe of the landslide are curved and the slip surface beneath the main body of the slide is planar at a depth of about 0.5-3.0 m. Thick vegetation makes determining landslide activity and geometry difficult, particularly because predominantly translational slides cause little disturbance or tilting of trees (Fig. 5). Benched topography at the heads of slide masses are one indicator of slope instability. Also, forward rotation and toppling at the toe of the slope typically accompany translational movement in this area, so forward tilting of trees there can indicate slope movement. In most cases, the tills lose much of their shear strength as movement proceeds, and the slides transform into earth flows on the lower part of the slope (Fig. 6). Such flows have convex snouts and disaggregated internal structure. Rotational slides (slumps) are far less common; where they occur, backward rotation of landslide heads can be identified by backward tilting of trees (Fig. 7). Slumps also generally transform into flows as they move downslope. Several locations along the bluffs show evidence of older deep-seated slumping that involved most of the bluff face, but most such slumps appear not to have been active for perhaps several decades. Some slumps in the area have thicknesses as great as 15 m, as judged by the width of the head, but most are 2-5 m thick. Earth flow and creep of near-surface layers parallel to the slope face are common along much of the bluff and can occur in combination

FIG. 5. Translational slide along bluffs north of Lake Forest. Trees on the landslide block remained vertical, which indicates translation on a planar shear surface.

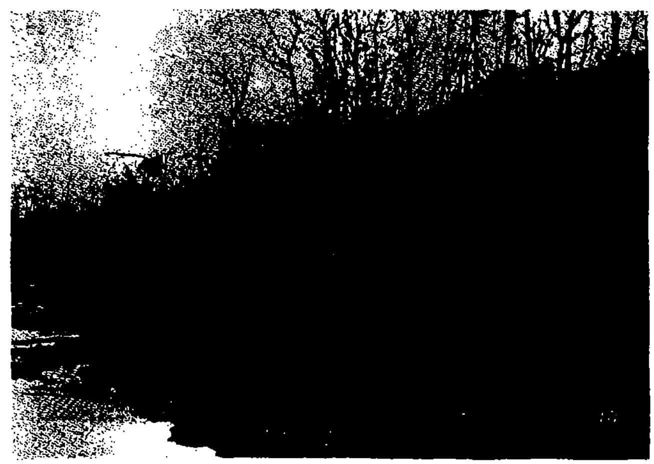

FIG. 6. Lower part of translational slide south of Lake Forest that has transformed into an earth flow. Note disruption of soil structure, forward tilting of trees, and convex slope profile in foreground.

FIG. 7. Rotational slump along bluffs near Lake Forest. Note backward rotation of trees on original ground surface of the slide block.

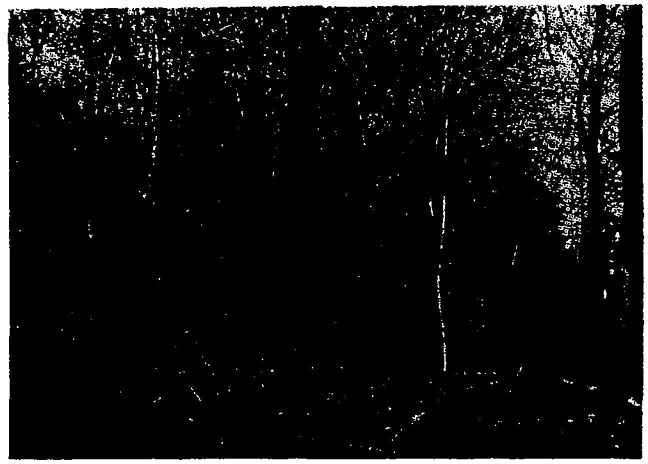

FIG. 8. Slope experiencing creep and flow of surficial material. Trees are tilted chaotically; some have sinuous trunks.

with deeper seated landsliding. Chaotic tilting of trees, hummocky topography, and bulging toes of slopes are common indicators of earth flow and creep (Fig. 8).

Till bluffs and lacustrine bluffs fail by similar landslide mechanisms. The coarser lacustrine material does tend to produce a slightly greater proportion of translational slides parallel to the slope face, and the finer grained till bluffs have a somewhat greater proportion of rotational failures. This is consistent with the behavior of the respective slope materials: sands and silts are predominantly frictional and tend to fail in an infinite-slope geometry (thin slabs parallel to the slope face with large length-to-width ratios); whereas, the shear strength of clays is dominated by cohesion, which generates curved, convex-upward failure surfaces that characterize slumps. This difference is subtle, however, and fairly thin translational slides predominate along both till and lacustrine bluffs, perhaps because weathered surface layers in clay till can become granulated and behave similarly to coarser grained materials.

Some parts of the bluff contain active landslides and obviously are currently retreating fairly rapidly by that mechanism. Other reaches of the bluff are covered by thick vegetation and appear to be stable. Close examination of such reaches, however, shows clear evidence of slope movement within at least the last several decades. Most of the low bluff has been graded and landscaped, so no record of previous landslide activity is preserved, but virtually the entire length of the high bluff shows evidence of historical activity. The thick vegetative cover provides a deceptive aura of stability, but most trees appear to be no older that 20-30 yr, and few, if any, are older than about 50 yr. Thus, even bluffs that appear intact and are covered by undisturbed trees may have been stable only for a few decades, and most such bluffs have benched topography and other features indicating fairly recent movement.

The width of the beach in front of the bluff appears to relate to the current state of landslide activity in many areas, presumably because wider beaches shield the bluff from direct wave attack. For example, the area south (downdrift) of the Highland Park water treatment plant has little or no beach and contains a long complex of active landslides. Trees near the base of the slope have toppled forward as the slides have transformed into flows and rotated forward. Sea walls, rip-rap, and other engineering works are being undermined by direct wave attack. Wide beaches are present north (updrift) of the plant, and bluffs there are currently relatively stable. However, even these bluffs show evidence of landslide activity within the last several decades, so their current stability may be ephemeral. Also, although many bluffs protected by wide beaches currently are stable with respect to translational and rotational sliding, they experience episodes of creep or flow of surficial layers.

RATES OF BLUFF RECESSION

Sorting out the relative effects of landsliding and other bluff-retreat processes and the rates at which they operate is a complex problem, and most research to date has focused on individual processes rather than on an integrated model. In terms of the effects of bluff recession on the public, however, the intricacies of the interaction of several processes and their varying rates is perhaps less important than the net effect over a given time period. Thus, the critical issue in terms of human planning is how far a given part of the bluff will recede in a relevant time period; for long-term human planning, time periods of 50-100 yr generally are of greatest interest.

Several studies of bluff retreat rates along other Great Lakes shorelines have been reported (e.g., Carter 1976, Kilgour *et al.* 1976, Quigley and Di Nardo 1980), and a detailed study similar to ours was conducted for Milwaukee County, Wisconsin, just north of our study area (Southeastern Wisconsin Regional Planning Commission 1989). Little has been published on bluff recession along the Illinois shore, however. Berg and Collinson (1976) and Lineback (1974) used maps and airphotos to determine rates of bluff-top retreat along 21 profiles for periods of a few years to more than 100 yr, and they compared rates in different areas. Larsen (1973) modeled bluff recession as a function of shoreline retreat at 26 evenly spaced locations between Waukegan and Wilmette to estimate spatial and temporal rate changes. These studies provide regional estimates or single-point measurements of retreat rates along the Illinois shoreline or analogous rate measurements from other Great Lakes shorelines with which we can compare our results. None, however, has involved a comprehensive documentation and interpretation of retreat rates along this shoreline over the time period of interest. More recently, we (Jibson *et al.* 1990; Jibson and Staude 1991, 1992) have conducted studies of bluff retreat rates along the Illinois shoreline, the results of which we discuss below.

Measuring Bluff Recession and Calculating Recession Rates

We divided the 30 km of bluffs from the north side of Wilmette harbor to the north side of the Great Lakes Naval Training Center into 300 segments, each 100 m long. Segments were defined by projecting perpendicular lines from a baseline bearing N. 20° W. and were numbered from south to north (Fig. 2). Data on bluff recession, bluff height, lithology, and the presence of shore-protective works were collected for each bluff segment. A limitation of using equal segment lengths is that some segments may straddle boundaries between areas of differing geologic, geomorphic, or engineering characteristics that may affect bluff recession, but the short segment length of 100 m minimizes this problem.

We used a common technique (e.g., Stafford and Langfelder 1971, Williams *et al.* 1979) of documenting bluff retreat by comparing bluff positions on historical maps and airphotos of different ages. Our density of measurements, however, is much greater than in most previous studies and thus provides an extensive database for analysis. We compared bluff positions from three data sources: 1:20,000-scale topographic maps made in 1872 by the U.S. Army Corps of Engineers (earliest maps at a usable scale), 1:14,400-scale airphotos taken in 1936 (earliest airphotos), and 1:14,400-scale airphotos taken in 1987 (most recent airphotos). The best method to document changes in bluff position is to measure the distance from the upper edge of the bluff to a reference feature. A recognizable feature on all data sources is the Chicago and Northwestern railroad grade, which roughly parallels the shoreline in the area. On the 1872 maps, we plotted the baseline, segmented the bluff, and measured the distance perpendicular to the baseline from the upper bluff edge to the center of the railroad grade at the midpoint of each segment. On the airphotos, we used a zoom-transfer scope to trace the position of the bluff edge onto U.S. Geological Survey topographic base maps (Evanston, Highland Park, and Waukegan $7^1/_2$' quadrangles) enlarged to 1:12,000 scale. We plotted the baseline and bluff segments on the maps and measured the distance to the railroad grade for each segment. Bluff recession at each segment was calculated by comparing the distances between each pair of data sources. Thus, we derived recession records for the 115-yr period from 1872 to 1987, the 65-yr period from 1872 to 1937, and the 50-yr period from 1937 to 1987.

Primary sources of location error include inherent airphoto distortion and imperfect registration of the map and airphoto on the zoom-transfer scope. Based on the scale and resolution of the airphotos and on measured registration inconsistencies on the zoom-transfer scope, we estimate that the combined location error from all sources for single features plotted from airphotos does not exceed 3 m; thus, distances measured between any two features are accurate within 6 m, and comparisons of two such distances are accurate within 12 m. Measurements directly from the 1872 maps are estimated to be accurate within 5 m; comparisons with measurements from airphotos are thus accurate within 11 m. If location errors are random, they should have little net effect on regional averages calculated from the large data base.

Amounts of Recession and Recession Rates

From 1872 to 1987 the average amount of recession for all bluff segments was 29 m; the maximum for any segment was 155 m. Average amounts of recession for the 1872-1937 and 1937-1987 periods were 20 m and 11 m, respectively; maximum amounts were 130 m and 85 m. These amounts of recession are large in view of the fairly dense development along most of the shoreline. To compare bluff retreat across different time intervals, we divided the amounts of retreat by the durations of the time periods to obtain the annual retreat rate.

Figure 9 shows annual retreat rates for the three time periods for the 300 bluff segments. Significant spatial variation in retreat rates appears related to contrasts between till and lacustrine bluffs. In the 1872-1987 and 1872-1937 periods (Figs. 9A and 9B), retreat rates of the lacustrine bluffs are much greater than the retreat rates of the till bluffs. Temporal variations are apparent between the 1872-1937 and 1937-1987 retreat rates (Figs. 9B and 9C). The 1872-1937 rates vary markedly between till and lacustrine bluffs, and local areas of high retreat rates are interspersed between areas of little or no retreat. In contrast, the 1937-1987 rates are more uniform throughout the area.

The rather spiky appearance of Figure 9 indicates that bluff segments having high retreat rates are adjacent to segments having much lower rates; thus, a highly irregular shoreline is expected. Viewed at regional scale, the shoreline appears quite regular (Fig. 2); but viewed at large scale (Fig. 10), local shoreline irregularities have sizes consistent with the differences in retreat rates shown in Figure 9.

Table 1 records mean recession rates for each time period and each section of bluff and changes in mean rates between periods; overall retreat rates for the entire bluff and rates for the low and high bluff also are shown. Retreat rates for the entire area are 20-30 cm/yr. Rates for individual sections of the bluff, however, define a much broader range, from 10 to 75 cm/yr. For each time period, the spatial rate variation relates to the lithology exposed. For 1872-1987, the two reaches where lacustrine sediment is exposed (LS and LN) have almost identical retreat rates that are much higher than the rates in the two till areas (HP and ZC). The 1872-1937 data show a similar rate contrast between lithologic types. In 1937-1987, the two till areas have almost identical rates, but the two lacustrine areas differ markedly from the till areas and from each other.

Figure 9D shows changes in retreat rates between the two time periods; positive values indicate a rate increase from the early to the late period. The lithologic control is striking. The rate-change data in Table 1 show that the lacustrine bluffs had much higher retreat rates from 1872 to 1937 than from 1937 to 1987 and that the till bluffs either had little change (ZC) or much higher rates (HP) in the later period. Interestingly, most local areas experienced large rate changes of as much as 120 percent, but, because some changes were positive and others negative, the net rate change for the entire area was rather modest—a 27 percent decrease.

Retreat rates for the low bluff (Table 1) decreased dramatically from 73.2 cm/yr in the early period to only 12.7 cm/yr in the late period. In contrast, rates for the high bluff vary only slightly between time intervals: the rate for 1872-1937 is 21.6 cm/yr, and for 1937-1987 it is 24.2 cm/yr. This difference of roughly 10 percent is insignificant as compared to the range of possible error in the method. Local rates along the high bluff vary considerably between till and lacustrine bluffs, however. For example, in the till bluffs along the Highland Park moraine, the retreat rate more than doubled from the early to the late period; just to the north along the northern lacustrine bluffs, the retreat rate was halved.

Factors Affecting Rate of Bluff Retreat

What causes the observed spatial and temporal variation in retreat rates along the bluffs? In this section, we examine and analyze how temporal variation in lake level and precipitation and spatial variation in bluff height, bluff lithology, and shore-protective works might affect bluff-retreat rates.

Temporal Changes in Lake Level. Change in lake level commonly is considered to be the major factor that controls changes in bluff retreat (e.g, Carter 1976, Vallejo and Degroot 1988). Short-term high stands of Lake Michigan generally lasting a few years have caused brief periods of increased bluff retreat (Lineback 1974, Berg and Collinson 1976, Vallejo and Degroot 1988). Gradual, long-term

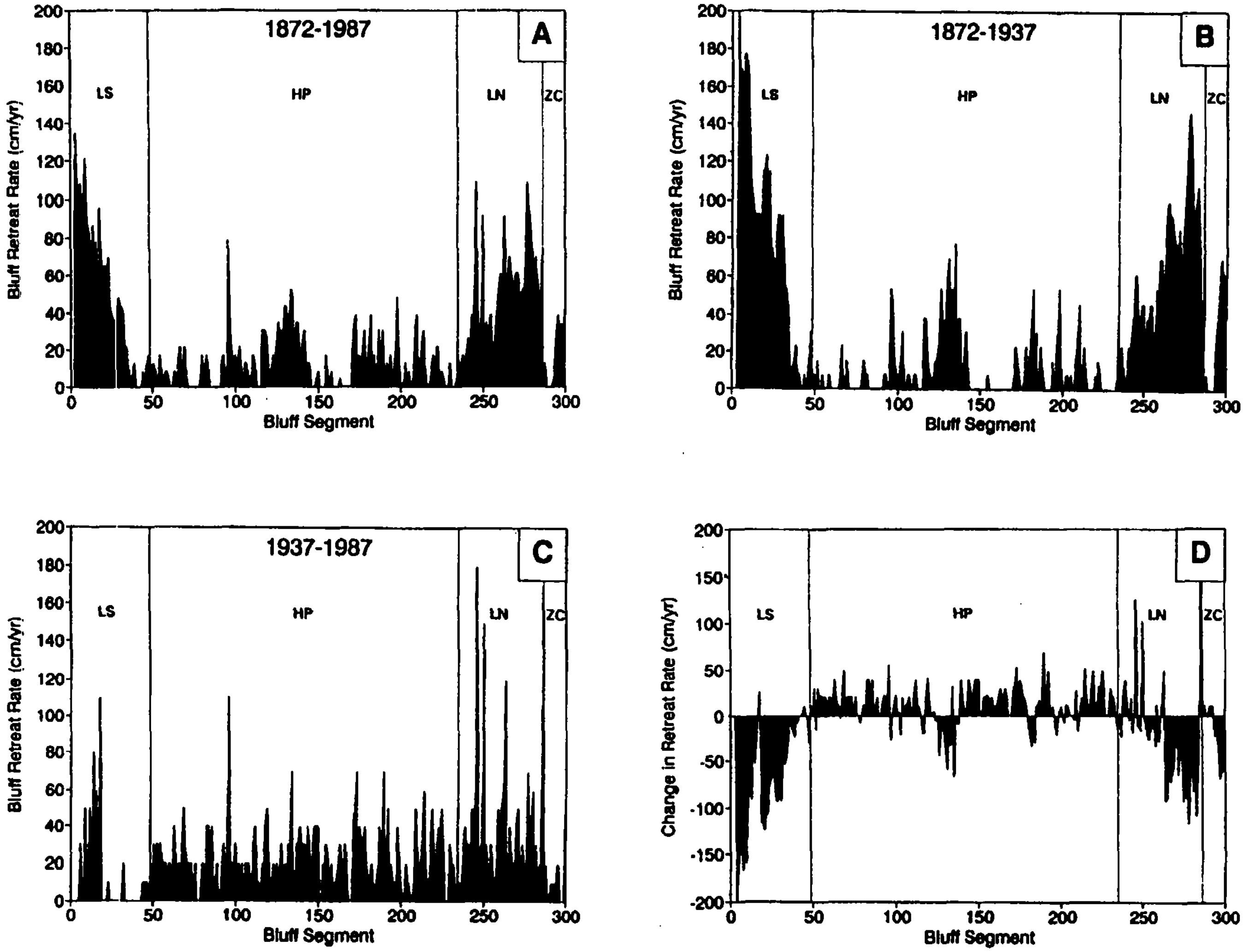

FIG. 9. Annual rates and changes in rates of bluff retreat between Wilmette and Waukegan; bluff segment numbers correspond to baseline in Figure 2. A, retreat rates for 1872-1987; B, retreat rates for 1872-1937; C, retreat rates for 1937-1987; D, changes in retreat rates between 1872-1937 and 1937-1987 (positive values where rate is greater in the later period). Vertical dashed lines show locations of geologic contacts; abbreviations as in Figure 2.

(decades to centuries) changes in lake level also affect bluff retreat according to most models of bluff-retreat mechanisms (e.g., Edil and Vallejo 1980, Vallejo and Degroot 1988). Because we are interested in time periods of 50-100 yr (relevant for human planning purposes), we measured some parameters of lake-level change between the 1872-1937 and 1937-1987 periods to detect (1) gradual changes in average lake levels and (2) differences in short-term extreme (maximum and minimum) lake levels.

We analyzed monthly and annual average lake-level data from the National Oceanic and Atmospheric Administration (no date); these data are derived from hourly and daily lake levels and thus implicitly account for durations as well as elevations of lake levels. We calculated the arithmetic mean, standard deviation, maximum, minimum, and total range of average annual lake levels for both time periods. We also calculated the percentage difference between various statistical measures for the data from the two time periods, and we used a statistical t-test to calculate the probability that the lake levels for the two time periods are statistically identical. To analyze extreme events, we determined the maximum and minimum monthly lake

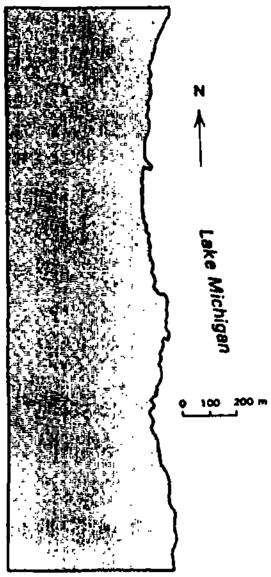

FIG. 10. Large-scale map showing the position of the upper edge of a part of the bluff south of Great Lakes Naval Training Center. Irregularities in the bluffline at this scale are consistent with rate variations between adjacent bluff segments shown in Figure 9.

levels for each year and determined statistical parameters for these data sets as described for average annual precipitation.

Table 2 shows that average annual lake levels for the two periods are remarkably similar: the total range in average annual lake level for both periods is 5.42 ft (1.65 m), and the difference in the means for the two time periods is only 0.01 ft (0.31 cm), or 0.1 percent. Maximum and minimum values of average annual lake level and the standard deviations all differ by less than 5 percent. Maximum and minimum monthly lake-level data likewise show remarkable similarity between the two periods. For all three pairs of data sets, the *t*-tests show that the data from the two time periods are statistically identical.

The data show no significant differences in average lake levels between the two periods that would indicate gradual, long-term changes in lake level. The similarity between the standard deviations for the two periods shows that variation about the means also was consistent between periods. The data also show no significant differences in maximum or minimum lake levels that would indicate differences in the number or magnitude of extreme lake-level events between the two periods. Therefore, *at this time scale*, local temporal changes in bluff retreat rates cannot be attributed to lake-level

TABLE 1. Bluff recession data.

Bluff Section (segments)	Recession Rate 1872-1987 (cm/yr)	1872-1937 (cm/yr)	1937-1987 (cm/yr)	Rate Change (cm/yr)	Rate Change (%)	Groins as of 1955 Number	Density (#/km)
LS (1-52)	46.8	73.2	12.7	-60.5	-82.7	9	1.7
HP (53-233)	13.2	10.2	22.6	12.4	121.6	64	3.5
LN (234-284)	45.8	59.2	30.4	-28.8	-48.6	26	5.1
ZC (285-300)	22.0	24.6	22.0	-2.6	-10.6	12	7.5
Low Bluff (1-52)	46.8	73.2	12.7	-60.5	-82.7	9	1.7
High Bluff (53-300)	20.9	21.6	24.2	2.6	12.0	102	4.1
Total Bluff (1-300)	25.4	30.5	22.3	-8.2	26.9	111	3.7

Note: LS, southern exposure of lacustrine deposits; HP, Highland Park moraine; LN, northern exposure of lacustrine deposits; ZC, Zion City moraine. Rate change is calculated by subtracting the 1872-1937 recession rate from the 1937-1987 rate.

fluctuations. This is not to say that changes in lake level do not affect retreat rates at any time scale, but rather that because lake-level fluctuation was virtually identical for both observed time intervals, it could not have caused differences in retreat rates between those intervals. Lake level certainly changes over shorter (days to years) and longer (several centuries or millennia) durations, but the time periods examined are appropriate for long-term planning in human terms.

Temporal Changes in Precipitation. Precipitation can affect bluff stability in several ways. In addition to affecting lake levels, precipitation also affects local ground-water conditions and surface runoff. Brief (hours to days), intense storms as well as longer periods (months to years) of increased rainfall probably affect bluff retreat rates, though possibly in different ways. We compared average annual and maximum monthly data for the two time periods in the same manner as for the lake-level data. Analysis of average annual data enables detection of gradual, long-term changes in precipitation amounts, and analysis of maximum monthly data provides an index to determine if the number or magnitude of shorter term, extreme precipitation events has changed between periods.

Table 2 shows statistical parameters for the databases analyzed. Somewhat more variation is present in the precipitation data than in the lake-level data. For average annual precipitation, differences in means, standard deviations, and ranges for the two periods differ by 8-16 percent; average precipitation in the 1937-1987 period was slightly greater and more variable than for the 1872-1937 period. The *t*-test probability that the 1872-1937 and 1937-1987 populations for average annual precipitation are identical is only 0.07, much lower than the probabilities for the lake-level data; however, a probabil-

TABLE 2. Changes in lake level and precipitation.

	Mean	Standard Deviation	P	Maximum Value	Minimum Value	Range
Average Annual Lake Elevation (ft)						
1872-1937	578.56	1.23		580.94	575.84	5.10
1937-1987	578.57	1.27	0.99	581.18	575.76	5.42
% Difference	0.1	3.2		4.4	1.5	5.9
Maximum Monthly Lake Elevation (ft)						
1872-1937	579.14	1.28		581.55	576.21	5.34
1937-1987	579.12	1.32	0.94	581.89	576.15	5.74
% Difference	0.3	2.9		5.9	1.1	7.0
Minimum Monthly Lake Elevation (ft)						
1872-1937	577.87	1.20		580.15	575.40	4.75
1937-1987	577.82	1.29	0.83	580.62	575.42	5.20
% Difference	1.0	6.9		9.0	0.4	8.6
Average Annual Precipitation (in)						
1872-1937	32.91	5.42		45.86	22.78	23.08
1937-1987	34.95	6.48	0.07	46.96	21.19	25.77
% Difference	7.9	16.4		4.3	6.2	10.4
Maximum Monthly Precipitation (in)						
1872-1937	5.89	1.68		11.28	2.82	8.46
1937-1987	6.31	1.75	0.20	11.69	3.33	8.36
% Difference	4.7	4.0		4.6	5.8	1.2

Note: P is the probability that the two populations (1872-1937 and 1937-1987) are statistically identical. Elevations are in feet (1 ft = 0.305 m); datum is 1955 International Great Lakes Datum. Precipitation is in inches (1 in = 2.54 cm).

ity of 0.07 still indicates that the hypothesis that the populations are significantly *different* is rejected at the 93 percent confidence level. A difference of less than 8 percent in mean annual precipitation probably is not enough to significantly affect bluff retreat processes and rates. Extreme values of average annual precipitation in these periods show even less variability than mean values. Minimum and maximum annual precipitation for the two periods differ by only 6.2 and 4.3 percent, respectively. Thus, as with lake levels, the differences in annual precipitation between the two periods is small enough that changes in bluff retreat rates cannot be attributed to changes in annual precipitation for the time interval analyzed.

Data for maximum monthly precipitation for a given year show even less variation: the means, standard deviations, and maximum values all differ by less than 5 percent between time periods, and the total ranges of the two data sets differ by only 1.2 percent. The *t*-test probability is 0.20; thus the hypothesis that the populations differ significantly is rejected at the 80 percent confidence level. Therefore, we detect no significant differences in extreme levels of monthly precipitation that would indicate variability in short-term extreme precipitation conditions between time periods that could significantly affect bluff retreat rates.

Bluff Height. Bluff height might be expected to influence retreat rates for at least two reasons, which have opposite effects. First, bluff height directly affects the stability of the bluff with respect to landsliding; all other factors being equal, increasing bluff height corresponds to decreasing slope stability (Edil and Vallejo 1980). Therefore, higher bluffs should be more susceptible to retreat from landsliding. Second, bluff height determines the volume of material that must be removed for a given amount of bluff retreat; thus, higher bluffs lose greater volumes of material per unit amount of retreat, and this greater amount of material requires more energy to remove it from the base of the bluff. In this case, higher bluffs correspond to lower retreat rates.

Figure 4 shows variation in bluff height along the shoreline; the high and low bluffs are distinct, but variation within the high- and low-bluff areas also is significant. We constructed two linear regression models, one for 1872-1937 and one for 1937-1987, to measure correlation between bluff height and retreat rate. In each model, we regressed the bluff height at each 100-m segment against the retreat rate for that segment. The model for 1872-1937 has an R^2 value of 27 percent and a high level (greater than 99 percent) of statistical significance, which indicates that for the early time period, a small but significant amount of the variation in retreat rates is explainable by variation in bluff height. The correlation is negative, that is, high retreat rates correlate with low bluff height. Figure 9 clearly shows that in the early period, the southern lacustrine bluffs, which have low bluffs, had very high rates of retreat, and this is reflected in the regression model.

The regression model for 1937-1987 has an R^2 value of only 2 percent and a low level (less than 95 percent) of statistical significance, and the regression model shows an opposite (positive) sense of correlation as compared to the regression model for the early period. Therefore, for the later period, we detect no significant correlation between bluff height and retreat rates. Thus, whatever influence low bluff height may have had on increasing retreat rates in the early period is not present in the later period.

The reason for the negative correlation between bluff height and retreat rate for the early period and the lack of correlation for the late period is not entirely clear. One possible reason may be the influence of Wilmette Harbor at the southern end of the area (Fig. 2). At present, Wilmette Harbor is a sediment barrier that has impounded large amounts of sand and created wide updrift beaches to the north that protect much of the low bluff from wave attack. Wilmette Harbor was constructed in 1910, so during much of the early period the low bluff immediately north of the harbor probably had much narrower fronting beaches and less protection from wave attack than at present. If lower bluffs retreat more rapidly than higher bluffs when subject to wave attack because less material must be removed, this difference in beach width between early and late periods could explain the results of the regression models.

Bluff Lithology. As discussed above, bluff lithology relates closely to spatial differences in retreat rates (see Fig. 9). Lithologic differences between different reaches of bluffs are primarily confined to the upper part of the bluff, which is subject to wave attack only in the most extreme conditions. The lacustrine deposits lie on silty clay tills exposed at the base of the bluff (Fig. 3). Therefore, differences in retreat rates between lithologically distinct parts of the bluffs must relate primarily to processes that affect the upper part of the bluff, such as landsliding

1-Year testing

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* HP, Deerfield, Bannockburn, Forest? Glencoe sanitary district

and rainfall-induced surface erosion, which are not controlled solely by wave attack.

Lacustrine bluffs, composed primarily of sand and silt, have greater retreat rates than till bluffs in all time periods and areas but one, the southern lacustrine bluff from 1937 to 1987. The sand and silt lack significant cohesive strength, which may render lacustrine bluffs more susceptible to surface erosion during rainstorms (Lineback 1974) and to wave attack during rare extreme events. Also, the sand and silt layers conduct ground water to the bluff face, where seeps are common. Interbedded clayey till layers create perched water tables and confine some permeable silt and sand layers causing buildup of high pore-water pressures; both the perched and confined ground-water conditions contribute to landsliding along the bluff (Hadley 1976, Mickelson *et al.* 1977, Edil and Vallejo 1980, Sterrett and Edil 1982, Edil and Bosscher 1988). Our observations indicate that the northern lacustrine bluffs contain the greatest concentration of landslides in the area.

The fine-grained till bluffs have a significant component of cohesive strength, which imparts greater overall shear strength to the till bluffs as compared to the lacustrine bluffs (DuMontelle *et al.* 1976). Although the clay till probably resists wave attack more effectively than lacustrine silt and sand, the till also is susceptible to deeper seated landsliding. Landslides are abundant along the bluffs of the Highland Park moraine, and, when they occur, they shift the location of the upper edge of the bluff by a large amount almost instantly.

Explanation of site specific engineering

The extreme rates of retreat and changes in retreat rates along the southern lacustrine bluffs probably are better explained by the distinct difference in bluff height there than by lithologic differences. As discussed previously, retreat of the low bluff may have occurred rapidly prior to construction of Wilmette Harbor, which created a sediment barrier that substantially widened the fronting beaches in much of the low bluff area.

If the lower retreat rates of till bluffs as compared to lacustrine bluffs were to persist, the till bluffs would become headlands and the lacustrine bluffs would recede to become reentrants: an irregular coastline would develop. Although local irregularities have developed (Fig. 10), the southwestern Lake Michigan shoreline is very regular and broadly arcuate, and the shape and character of the shoreline do not change abruptly at lithologic boundaries (Fig. 2). Rate variations since 1872 between till and lacustrine bluffs do not explain the observed geomorphology of the bluffline and thus must not persist for long periods of time. Therefore, retreat rates of bluffs composed of different materials must vary in time to produce parallel (in map view) bluff retreat on a regional scale. For example, the more than doubling of the retreat rate along the Highland Park moraine between the early and late periods corresponds in time with substantial reductions in retreat rates in adjacent lacustrine bluffs (Table 1). The 115-yr observation period is too brief to unequivocally document this phenomenon, but the regular coastline strongly supports a model of long-term parallel bluff retreat in the area.

Shore-Protective Works. Almost the entire length of the shoreline along the bluffs currently has some type of artificial shore protection. Types of protective works include groins, sea walls, revetments, rip-rap, and breakwaters, all of which vary in size, age, and quality of construction. Virtually all of the shore-protective works now present along the shoreline have been built since about the late 1920s; before then, fewer shore-protective works existed along the bluffs, and some reaches were entirely unprotected. Thus, during most of the early time period, the bluff retreated in a less protected state relative to the later period, in which a wider variety, higher density, and better quality of shore-protective works were present. Surprisingly, data from Table 1 show that the overall rate of retreat along the bluffs has not changed significantly; in fact, the retreat along the high bluff has actually increased slightly. The only exception, the reduction in retreat rate along the low bluff, probably relates to the construction of Wilmette Harbor, the largest sediment barrier south of the Great Lakes Naval Training Center. At this simplistic level of analysis, we could conclude that the shore-protective works built since the early part of this century have had little or no impact on the regional rates of bluff retreat. Figure 9 shows that the spatial distribution of retreat rates does differ between time periods. Figure 9B (1872-1937) shows several distinct areas of high retreat rates and intervening areas of little or no retreat; Figure 9C (1937-1987) shows a more even spatial distribution of rates. Therefore, construction of shore protection since the 1930s may have changed the spatial distribution of retreat rates, even if it did not affect the overall regional rate.

A report by the Illinois Division of Waterways (1958) provides a good database to more closely examine the effects of one type of shoreline protection—groins. Groins are vertical barriers, extending from the beach offshore, designed to trap sediment moving along shore and thus to widen beaches and protect bluffs from wave attack. Beginning in the late 1920s, an ambitious groin-building program began along much of the shoreline. Although many of these groins were built to replace an earlier generation of deteriorated rock piers (C.W. Shabica, Northeastern Illinois University, written commun., 1992), the Illinois Division of Waterways (1958) indicates a substantial increase in the number of shoreline structures dating from the 1920s and 1930s. By the late 1930s, many groins were in place, and this episode of groin construction continued into the 1950s. Most groins constructed along the bluffs during this period were of fairly consistent size and type (Illinois Division of Waterways 1958). Thus, comparing retreat rates along different parts of the bluffs between the two periods should provide insight for evaluating the effects of a substantial increase in the number and density of shore-protective structures on retarding bluff recession.

We used Larsen's (1973) compilation of the data from the Illinois Division of Waterways (1958) on the number and distribution of groins in the area built between 1872 and 1955. About 95 percent of these groins were built after 1920. Table 1 records the numbers of groins built by 1955 along each section of bluff and their density (number of groins per kilometer). The data show that these groins had no consistent effect on bluff retreat rate. The area having the greatest groin density (ZC) had a negligible change in retreat rate. The area having the lowest groin density (LS) experienced an 80-percent *reduction* in retreat rate, while the rate along the Highland Park moraine, which had twice the groin density, more than doubled. Along the high bluff, which contains 92 percent of the groins and has a high groin density, the retreat rate actually increased slightly; whereas, along the low bluff, which has a much lower groin density, the retreat rate decreased by more than 60 percent. Thus, construction of this early generation of groins neither enhanced nor degraded bluff stability in a consistent manner. The evening out of the spatial distribution of bluff retreat rates in the later period, therefore, probably cannot be attributed to this generation of groins.

The observations of the effects of shore-protective works on bluff retreat rates indicate that (1) shore-protective works may have created a more uniform spatial distribution of bluff retreat rates in the later period, but (2) these engineered works had little, if any, effect on the overall regional rate of bluff retreat. These conclusions probably do not apply to shore protection built in the last few years, which has not been in place long enough to have had a significant effect on retreat rates in the later period.

SEDIMENT VOLUME PRODUCED BY BLUFF RETREAT

One of the geologic effects of bluff retreat is the addition of sediment to the littoral transport system along the Lake Michigan shoreline. Availability, distribution, and movement of sediment along shore significantly affects shoreline geologic processes as well as human planning. Therefore, we used the bluff retreat rates, in conjunction with data on bluff geometry and sediment grain-size distribution, to estimate the volume of sediment contributed to the littoral system by bluff recession.

We conducted cone-penetration tests (CPT) at 10 sites in the study area. CPT involves pushing a conically tipped steel rod having a cross-sectional area of 15 cm^2 into the ground. Strain gages in the rod measure the load on the tip of the probe as well as the friction along the lateral edge (sleeve) of the probe. Published correlations between values of tip and sleeve resistance allow interpretation of the grain size of the material through which the cone is pushed (Meigh 1987). Because CPT grain size is interpreted by soil behavior rather than by direct measurement of particle size, boundaries between grain-size classes are qualitative.

We located penetrometer soundings within 15 m of the edge of the bluff; soundings extended to a depth below the base of the bluff (below lake level) in most cases. CPT grain-size data confirmed our general stratigraphic model (see Fig. 3) of the bluffs, but many additional sediment layers as thin as about 2.5 cm (the practical resolution of the CPT) were detected. For each CPT log, we estimated the amount of sand and gravel (grouped together), silt, and clay as a proportion of the total bluff height. We then linearly interpolated these proportions between each CPT log to construct a model of grain-size distribution for each 100-m bluff segment in the area (Fig. 11). Clearly, clay predominates the system; even including bluffs capped by lacustrine sediment, clay makes up 40-70 percent of the total throughout the area. The silt portion is remarkably constant at about 20 percent of the total, and the sand portion varies from 10-15 percent in till bluffs to 30-40 percent in bluffs

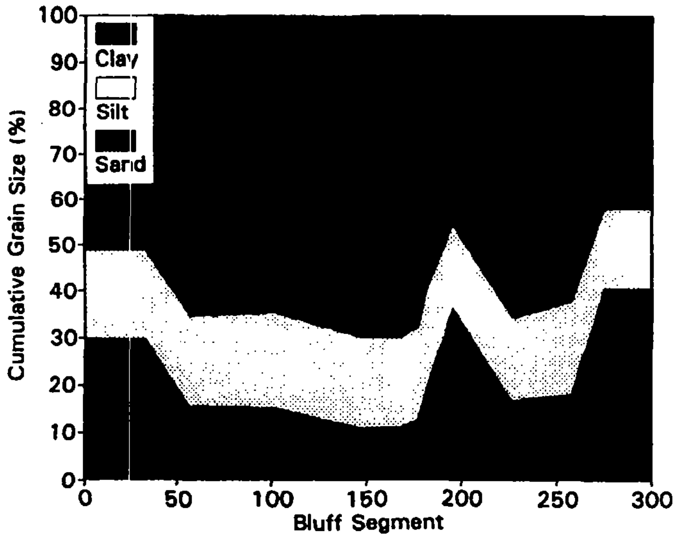

FIG. 11. ***Model of grain-size distribution along the bluffs derived by interpolating between 10 cone-penetration test sites spaced roughly uniformly along the bluff.***

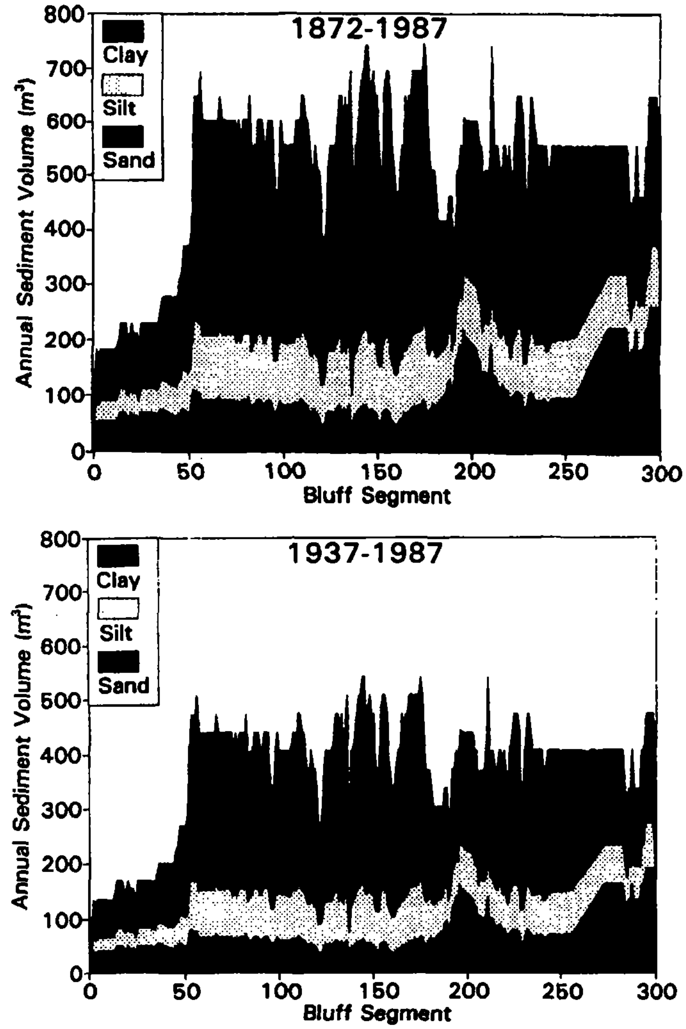

FIG. 12. ***Model of annual sediment volume (by grain-size class) caused by bluff retreat in the study area. A, volumes calculated using 1872-1987 average regional retreat rate; B, volumes calculated using 1937-1987 average regional retreat rate.***

capped by lacustrine sediment. Grain-size distributions interpreted from CPT data are consistent with published grain-size data from laboratory analysis of drill samples of bluff materials in the study area (DuMontelle *et al.* 1976).

We estimated annual volumetric loss from the bluffs by assuming parallel cross-sectional bluff retreat. In this way, the volume of material removed annually from each bluff segment can be calculated by multiplying the bluff height (in meters) by the segment length (100 m) by the retreat rate (in meters/year). We applied the regional average retreat rate to all bluff segments because of the great local temporal variation in rates and because the average regional rate represents long-term conditions; both the 115-yr (1872-1987) rate and the most recent 50-yr (1937-1987) rate were used for comparison. The total volume per segment was then multiplied by the sediment grain-size proportions for each segment to yield an estimate of sediment volume by segment and by grain size for the entire study area (Fig. 12). Finally, we summed the respective annualized volumes of sand and gravel, silt, and clay for the entire area; we also divided these volumes by the total bluff length (30 km) to determine sediment volume per unit bluff length (Table 3).

Clay and silt normally are removed from the littoral system because they are carried in suspension away from the shoreline and settle offshore in deeper water. Therefore, the sand volume is of greatest interest for the near-shore environment. The two retreat rates used yield annual sand volumes of 23,000-32,000 m^3 over the entire 30 km of bluff, which averages out to about 1 m^3 of sand per linear meter of bluff (Table 3).

DISCUSSION AND CONCLUSIONS

Retreat rates from our study are similar to those from previous studies of this area (Larsen 1973,

TABLE 3. Sediment volume from bluff retreat.

Grain Size	1872-1987 Rate Volume (m^3/yr)	1872-1987 Rate Volume/Length (m^3/m/yr)	1937-1987 Rate Volume (m^3/yr)	1937-1987 Rate Volume/Length (m^3/m/yr)
Sand and Gravel	31,892	1.06	23,317	0.78
Silt	29,105	0.97	21,280	0.71
Clay	92,599	3.09	67,703	2.26
Total	153,596	5.12	112,300	3.74

Lineback 1974, Berg and Collinson 1976). A detailed study of bluff recession between 1963 and 1985 along about 50 km of bluffs in Milwaukee County, Wisconsin, just north of our study area, indicates that bluff recession rates range from less than 15 cm/yr to almost 400 cm/yr; the weighted average over the entire area is about 30 cm/yr (Southwestern Wisconsin Regional Planning Commission 1989), only slightly greater than rates along the Illinois bluffs. Published recession rates for other Great Lakes shorelines composed of similar lithologic units are significantly greater than our rates; for example, long-term (100-150 yr) average rates of 50-280 cm/yr have been documented for several reaches of the Lake Erie shoreline (Carter 1976, Kilgour *et al.* 1976, Quigley *et al.* 1977, Quigley and Di Nardo 1980). Lithologically similar bluffs in some areas along oceanic coastlines retreat by mechanisms similar to those operating along Great Lakes bluffs, so comparisons with rates there also is of interest. Recession rates along coastal till bluffs in the British Isles are much greater than along the Lake Michigan bluffs in Illinois: rates along part of the Northern Ireland coast are 21-84 cm/yr (McGreal 1979), and rates in southern England are 25-510 cm/yr (Barton and Coles 1984, Hutchinson 1973). Lower retreat rates along Lake Michigan compared to oceanic bluffs are not surprising because of the greater wave energy along oceanic coasts.

Our results regarding the influence of various factors on retreat rates appear at odds with some conclusions of previous studies as well as with intuition. Changes in bluff retreat rates commonly have been expected to correlate with fluctuations in lake level, and over brief time intervals (a few years) they have been shown to do so (e.g., Berg and Collinson 1976, Carter 1976, Quigley *et al.* 1977, Quigley and Di Nardo 1980, Vallejo and Degroot 1988). Over time periods of several decades, however, which are of greatest interest for human planning, average lake levels and the amount of variation in lake levels are constant, and extreme events that trigger short-term catastrophic bluff retreat appear to occur with the same magnitude and frequency over these time periods. Because no long-term variation in average or extreme lake-levels can be detected, lake-level fluctuations in the next 50-100 yr probably will be similar to those of the past 50-100 yr. The same conclusions apply to precipitation levels.

The fairly uniform regional retreat rates between the early period of less shoreline engineering and the late period of more intensive shoreline engineering indicate that, although shore-protective works may have altered the spatial distribution of retreat rates, they had little effect on the overall rates of retreat. The absence of correlation between groin construction and retreat rates argues against the conventional wisdom at the time of their construction—that groins would produce wider beaches that would protect bluffs from wave attack. The ineffectiveness and even detrimental effects of groins on bluff stability have been documented more recently (Inman and Brush 1973, Larsen 1973, Mickelson *et al.* 1977). Existing data, however, are insufficient to evaluate the effects of the most recent shore-protective works that have been in place only for a few years. Quote

Figure 9 shows that some individual bluff segments or small groups of bluff segments had very large retreat rates relative to adjacent segments. The regular shape of the shoreline at regional scale (Fig. 2) indicates that radical local differences in retreat rate do not persist over long periods of time. Data from Figure 9, however, indicate that local irregularities in the shoreline should have dimensions of 50-100 m. Bluffline irregularities shown in Figure 10 have such dimensions and thus are consistent with the recession data in Figure 9.

Of the factors examined, only variation in the lithology of the upper part of the bluff correlates with local changes in retreat rate. Over the 115-yr period, retreat rates of lacustrine bluffs are much greater than those of till bluffs (Table 1). Retreat rates in all units except the Zion City moraine vary substantially between early and late intervals; rates in lacustrine bluffs decrease, and rates in the bluffs formed by the Highland Park moraine increase. However, the minor changes in the regional retreat rates between the two time periods (particularly for the high bluff) and the fairly linear, regular shape of the southern Lake Michigan shoreline both indicate that spatial and temporal changes in retreat rates balance out over time periods of several decades to centuries and that a uniform regional rate of retreat prevails. For the last 115 yr, that retreat rate is about 20-25 cm/yr, a significant amount both in human and geological terms. Although ~~bluff segments~~ composed of materials more susceptible to surface erosion and landsliding than adjacent segments will experience anomalously high rates of retreat for limited periods of time, the data indicate that rates in such areas will eventually decrease and allow adjacent segments to "catch up." Although the mechanism by which this occurs is uncertain, we surmise that the long-term regional bluff retreat rate is controlled by the rate of erosion and retreat of the shoreface (extending from the beach at the base of the bluff to the lake bed offshore) rather than by lithologic variations in the upper part of the bluff. Throughout the area, the base of the bluff, the beach platform, and the shoreface all consist of hard clay till, covered in places by a thin veneer of sand and gravel (Foster and Folger, this volume). ~~We can rea-~~sonably infer that a shoreface having essentially uniform lithology and physical properties and exposed to fairly uniform wave energy erodes and retreats at a uniform rate throughout the area. Local episodes of rapid bluff recession temporarily widen the beach platform and thus increase the distance from the base of the bluff to the shoreface, which does not necessarily react by eroding more quickly. In such areas, waves break farther from the bluff base, and wave energy will be dissipated before reaching the base of the bluff. This effectively retards bluff recession until the shoreface retreats closer to the bluff. Thus, the uniform lithology and erosion rate of the shoreface could effectively damp excessive bluff retreat in any one location and therefore constrain the geometry of the shoreline to its fairly linear form.

For the most recent period of observation, 1937-1987, retreat rates along the till bluffs are about the same as the long-term regional average. Retreat rates in the northern lacustrine bluffs are much greater than the regional average but are lower than those for the 1872-1937 interval; this decrease in retreat rate might be expected to continue if rate changes balance out through time. Rates for the southern lacustrine bluff are much lower for the late time interval as compared to the early time interval. Retreat rates there might be expected eventually to increase toward the regional average unless shore-protective works or widened beaches maintain the low rate.

The minute amount of sand contributed by bluff recession to the littoral system is consistent with recent surveys (e.g., Foster and Folger, this volume; Shabica *et al.* 1991) of nearshore sand volumes, which indicate that only thin, patchy sand bodies of small total volume are present along the Illinois shoreline. The predominantly fine-grained texture of the bluff materials thus has created a supply-limited littoral transport system.

What are the human consequences of the 20-25 cm/yr bluff recession rates in this area? Development in most of the area consists of medium-density single-family housing (large homes on fairly large lots) ranging in age from new to nearly 100 yr old. Setbacks from the bluff vary from almost zero to a few tens of meters. If the regional retreat rate prevailed everywhere (which it does not), then a house would need a 20-25 m setback from the bluff to survive 100 yr. Few houses have such large setbacks. Even though regional retreat rates are fairly constant, Figure 9 shows that retreat rates vary substantially from place to place for a given 50-100 yr period. The retreat that a specific part of the bluff might experience in any 50-100 yr period probably depends on several factors at that site and at nearby parts of the bluff: (1) the type and quality of shore protection, (2) the rate of retreat in the previous 50-100 yr period, (3) the local lithology and geotechnical properties of the bluff material, (4) the width of the fronting beach, and (5) the geometry of the shoreface in front of the bluff. Therefore, the data and conclusions from this study are relevant for regional planning rather than for site-specific engineering. Any planning for construction near the bluffs, however, must anticipate some amount of bluff recession and stipulate sufficient setback to insure the integrity of structure for its anticipated life.

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what are site specific
– retreat rate not uniform over short periods

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Appendix III: Supplemental Information for Figure 8

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART		
COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	
	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	
	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	
	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	
	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

Exhibit D

Amounts and Rates of Bluff-Top Recession Along the Lake Michigan Shoreline at Fort Sheridan, Illinois, From 1872-1987, Randall W. Jibson, U.S. Geological Survey, Open-File Report 03-231, (1994) (Released 2003)

U.S. Department of the Interior
U.S. Geological Survey

AMOUNTS AND RATES OF BLUFF-TOP RECESSION ALONG THE LAKE MICHIGAN SHORELINE AT FORT SHERIDAN, ILLINOIS, FROM 1872-1987

By Randall W. Jibson

Open-File Report 03-231

U.S. Geological Survey
Golden, Colorado

Introduction

brief report is being released as a result of a public request for data regarding amounts and rates of bluff-top recession at Fort Sheridan, Illinois, which is located along the Lake Michigan shoreline. Previously published reports (Jibson and Staude, 1992; Jibson and others, 1994) contained graphical representations of bluff-recession data along the Lake Michigan shoreline from Wilmette to Waukegan, Illinois; this report contains a table of the numerical data for the Fort Sheridan segment of the previous study area.

Measuring Bluff Recession and Calculating Recession Rates

As described in previously published reports (Jibson and Staude, 1992; Jibson and others, 1994), the 30 km of bluffs along the Illinois shoreline of Lake Michigan from the north side of Wilmette harbor to the north side of the Great Lakes Naval Training Center were divided into 300 segments, each 100 m long. Segments were defined by projecting perpendicular lines from a baseline bearing N. 20° W. and were numbered from south to north. We documented bluff retreat by comparing bluff positions on historical maps and airphotos of different ages. We compared bluff positions from three data sources: 1:20,000-scale topographic maps made in 1872 by the U.S. Army Corps of Engineers, 1:14,400-scale airphotos taken in 1936, and 1:14,400-scale airphotos taken in 1987. On each data source, we measured the distance from the upper edge of the bluff to the Chicago and Northwestern railroad grade, which roughly parallels the shoreline in the area. On the 1872 maps, we plotted the baseline, segmented the bluff, and measured the distance perpendicular to the baseline from the upper bluff edge to the center of the railroad grade at the midpoint of each segment. On the airphotos, we used a zoom-transfer scope to trace the position of the bluff edge onto U.S. Geological Survey topographic base maps (Evanston, Highland Park, and Waukegan 7½' quadrangles) enlarged to 1:12,000 scale. We plotted the baseline and bluff segments on the maps and measured the distance to the railroad grade for each segment. We measured amounts of recession for the 115-yr period from 1872 to 1987 and the 50-yr period from 1937 to 1987. Average annual recession rates were calculated by dividing the total recession for a given time period by the length of that time period.

Primary sources of location error include inherent airphoto distortion and imperfect registration of the map and airphoto on the zoom-transfer scope. Based on the scale and resolution of the airphotos and on measured registration inconsistencies on the zoom-transfer scope, we estimate that the combined location error from all sources for single features plotted from airphotos does not exceed 3 m; thus, distances measured between any two features are accurate to within 6 m, and comparisons of two such distances are accurate to within 12 m. Measurements directly from the 1872 maps are estimated to be accurate to within 5 m; comparisons with measurements from airphotos are thus accurate to within 11 m. If location errors are random, they should have little net effect on regional averages calculated from the large data base.

Bluff Recession at Fort Sheridan

Figure 1 shows the segmentation of the bluffs at Fort Sheridan, Illinois. Fort Sheridan includes segments 166-193 of the original segmentation scheme described above and published previously (Jibson and Staude, 1992; Jibson and others, 1994). Table 1 contains bluff-recession data for these segments, including the total amount of bluff-top recession (in meters) and average annual recession rates (in meters/year) for 1937-1987 and 1872-1987.

References

Jibson, R.W., and Staude, J.M., 1992, Bluff recession rates along the Lake Michigan shoreline in Illinois: Association of Engineering Geologists Bulletin, v. 29, p. 103-117.

Jibson, R.W., Odum, J.K., and Staude, J.M., 1994, Rates and processes of bluff recession along the Lake Michigan shoreline in Illinois: Journal of Great Lakes Research, v. 20, p. 135-152.

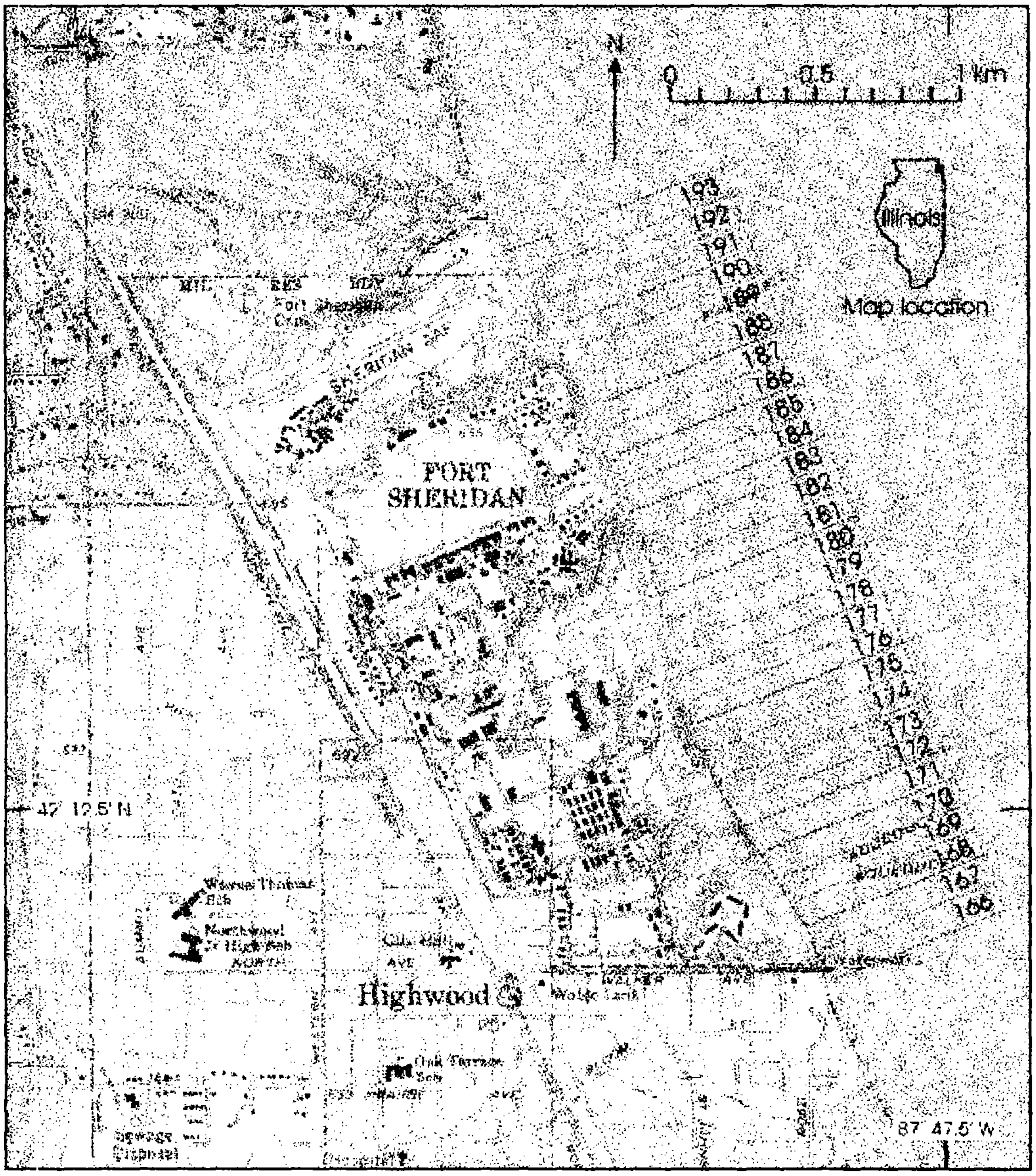

Figure 1.– Map showing segmentation of bluffs at Fort Sheridan, Illinois. Each bluff segment is 100 m long; numbering scheme is described in the text. Base map is U.S. Geological Survey Highland Park 7.5' quadrangle (contour interval 5 feet, published scale 1:24,000)

Table 1.-- Amounts of bluff-top recession and recession rates at Fort Sheridan, Illinois.

Bluff Segment	Total bluff-top recession (m)		Average annual recession rate (m/yr)	
	1937-1987	1872-1987	1937-1987	1872-1987
166	19	19	0.38	0.16
167	16	19	0.32	0.16
168	32	30	0.64	0.26
169	0	no data	0.00	no data
170	0	no data	0.00	no data
171	17	40	0.34	0.34
172	21	41	0.42	0.35
173	20	40	0.40	0.34
174	0	40	0.00	0.34
175	15	25	0.30	0.22
176	22	32	0.44	0.28
177	20	31	0.40	0.27
178	22	41	0.44	0.35
179	10	24	0.20	0.21
180	13	24	0.26	0.21
181	8	22	0.16	0.19
182	8	17	0.16	0.15
183	9	20	0.18	0.17
184	0	4	0.00	0.03
185	3	6	0.06	0.05
186	12	12	0.24	0.10
187	14	no data	0.28	no data
188	19	no data	0.38	no data
189	23	23	0.46	0.20
190	20	20	0.40	0.17
191	22	22	0.44	0.19
192	25	31	0.50	0.27
193	21	29	0.42	0.25

This page is <URL: http://pubs.usgs.gov/of/2003/ofr-03-231/Fort_Sheridan.html>
Last Modified Fri Jul 25 08:28 EDT 2003
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Exhibit E

Bluff Erosion, Recession Rates, & Volume Losses on the Lake Michigan, Richard C. Berg and Charles Collinson, (1976)

Bluff Erosion, Recession Rates, & Volumetric Losses On The Lake Michigan
By Richard C. Berg and Charles Collinson 1976
HR551.45 B493

Areas Of Bluff Erosion
Page 4

Areas of bluff erosion and instability along the Illinois shore can be placed in three categories.

2. Large areas where erosion is of short duration, is related to the present high-water cycle, and has resulted in significant recession. Two areas fall into this category. One is at the southern end of Fort Sheridan where more than 50,000 cubic yards of material has been lost from the shore since 1964 and an average of 15 feet of recession has been measured. The second is in the southernmost Lake Forest and northernmost Fort Sheridan where 45,000 cubic yards of material has been contributed to the lake and the shore has receded an average of 33 feet since 1964. Virtually all of the recession identified in both areas has occurred since 1969. The Lake Forest-Fort Sheridan area is later discussed in detail.

Resource for FOIA request: Bluff contours on U.S. Corps of Engineers maps for 1910-1911 and 1872-1873(scale 1:20,000

Table 5-Bluff Recession at Lake Bluff, By Periods (pg 12)

Recession area	1872 to 1910 (38 years) (ft)	1910 to 1975 (65 years) (ft)	1872 to 1975 (103 years) (ft)
Over-all recession	157	110	267
Area north of Shore Acres Country Club (northernmost 2400 ft of shore)	235	171	406
Area south of Shore Acres Country Club (11,900 ft of shore)	140	88	228

Table 11-Total Bluff Recession At Lake Forest Preserve, 1872 to 1975 (pg 20)

Period	Recession (ft)
1910 to 1975	50.3
1872 to 1975	104.1

Page 22- Although erosion at Highland Park, Glencoe, and Winnetka is much less spectacular than the erosion now occurring at Lake Forest and Lake Bluff, the volume of material lost to the lake in the three communities since 1872 is considerable. The main difference is that approximately 11 miles of shore edging those communities was involved, whereas less than 2 miles was involved in the Lake Forest-Lake Bluff losses.

About 47,000,000 cubic yards of sediment has been lost from the 11-mile reach. At Winnetka, the total recession for all parts of the shore during the past 100 years has been 28 feet, and total sediment loss has been 4,000,000 cubic yards. Recession of the Glencoe shore for the century averaged 21 feet, a loss of 10,000,000 cubic yards of material. Highland Park's shoreline of more than 5 miles receded 43 feet in 100 years, involving a loss of about 33,000,000 cubic yards of material. Although these losses are large, the occurred mainly before 1910 when shore protection measures were much less adequate than at present.

Exhibit F

Email Correspondence with Randall W. Jibson, U.S. Geological Survey, April 15, 2003, June 20, 2003, (October 29, 2003)

Steven Pollack

From: Randall W Jibson [jibson@usgs.gov]
Sent: Tuesday, April 15, 2003 1:38 PM
To: Steven Pollack
Subject: Re: Fort Sheridan, IL

Dear Mr. Pollack,

I read your e-mail with great interest. It has been quite some time since I did that work, and I had to take a few minutes to refresh my memory about what I had said. One thing I do recall is that that study got a rather cool reception in the area, mainly because it found that, in the long term, shore-protection measures have no net effect on erosion rates--not a particularly popular point of view.

My study was done as part of the larger umbrella of the Southern Lake Michigan Coastal Erosion study. The CD-ROM you mentioned is the best repository of data and conclusions I know of, although many other products were published in various media. Your best bet in tracking down more info is to contact John Haines (jhaines@usgs.gov), the Program Coordinator for Coastal and Marine Geology, who is located at our headquarters in Reston, Virginia.

I think your characterization of my conclusions is accurate. I think it is also possible that the Army did some site-specific studies that would support their course of action. As stated in my conclusions, bluff-retreat rates at different locations can vary dramatically over time scales of decades--it's when we move to centuries that things appear to even out and produce a fairly regular shoreline. Thus, the Army may have quite appropriately concluded that with certain shore-protective measures, the bluff would be "stable" for some period of years that they consider the lifespan of the project. You, on the other hand, can also appropriately conclude that eventually the bluff will retreat and expose the buried waste. It all depends on the time context of the statements. This becomes a legal/semantic/engineering issue that courts have to sort out.

I do find it ironic that two opposing camps in this controversy can look at the same body of work and draw opposite conclusions to support their positions. In general, the USGS tries to avoid taking sides in conflicts such as this; rather, we try to maintain scientific objectivity and simply provide data, analysis, and supported conclusions that can be used by all members of the public, including private citizens as well as other government agencies. Neutrality can be a tricky balancing act, but it is the only way to retain our scientific credibility. Science done in the role of an advocate of a specific position is virtually always biased; it's not that hard to assemble a group of observations that could support almost any point of view. Our job is to objectively look at all the data and try to explain those data in the simplest and most rational way, and then let the political chips fall where they may.

Good luck in your endeavors. Let me know if I can be of further assistance.

Randy Jibson

At 09:38 PM 4/13/2003 -0500, you wrote:
>Dear Mr. Jibson:
>
>I am an environmental activist working on issues surrounding Landfill 7 at
>the former Fort Sheridan. The Army plans to cap this landfill in place
>along the lake front and I am opposed to this plan based on shoreline
>erosion that will affect the cap integrity over time. I want the waste

>excavated and moved to a properly planned landfill.
>
>I have been at this for the past six years and my work can be seen at
>www.familyjeweler.com/fortweb.htm
>
>I just came across your study;
>
>Rates and Processes of Bluff Recession Along the Lake Michigan
>Shoreline in Illinois 1994
>
>Randall W. Jibson and Jackson K. Odum
>
>U.S. Geological Survey
>Box 25046, MS 966, Denver Federal Center
>Denver, Colorado 80225
>
>Discussion and Conclusion
>
>".........What are the human consequences of the 20-25cm/yr bluff
>recession rates in this area? Development in most of the area consists
>of medium-density single-family housing(large homes of fairly large
>lots)ranging in age from new to nearly 100 yr old. Setbacks from the
>bluff vary from almost zero to a few tens of meters. If the regional
>retreat rate prevailed everywhere(which it does not), then a house
>would need a 20-25 m setback from the bluff to survive 100 yr. Few
>houses have such large setbacks. Even though regional retreat rates
>are fairly constant, Figure 9 shows that retreat rates vary
>substantially from place to place for a given 50-100 yr period. The
>retreat that a specific part of the bluff might experience in any
>50-100 yr period probably depends on several factors at that site and
>at nearby parts of the bluff: (1) the type and quality of shore
>protection, (2) the rate of retreat in the previous 50-100 yr period,
>(3) the local lithology and geotechnical properties of the bluff material,
>(4) the width of the fronting beach, and (5) the geometry of the shoreface
>in front of the bluff. Therefore, the data and conclusions from this study
>are relevant for regional planning rather than site-specific engineering.
>Any planning for construction near the bluffs, however, must anticipate some
>amount of bluff recession and stipulate sufficient setback to insure the
>integrity of structure for it's anticipated life."
>
>It would seem that your conclusion is in contrast to the Army idea that
>this single point can be protected along an eroding bluffline over long
>periods of time when the study clearly states that regardless of the
>rate of local recession, slower recession areas invariably catch up to
>higher recession areas. "Bluffs that contain lake-plain sand and silt
>have higher retreat rates than clay-till bluffs. However, the bluffs
>have little curvature across these boundaries indicating that the
>variations average out over time, producing long- term parallel bluff
>retreat. "
>
>This would seem to be the smoking gun in support of my conclusion that
>Landfill 7 can never be engineered against failure due to area wide
>recession in the long run.
>
>I find it odd that I only recently became aware of this study when the
>Army clearly knew about it. I say this because of a line I remember
>that they quoted in the RI-RA/FS that erosion studies are for "regional
>planning rather than site-specific engineering", right out of the above
>paragraph. Now that I see the study and the conclusions which are in
>stark contrast to their plans, I wonder if this quote is misused by
>them. They seem to be saying that the regional, and not site specific
>nature or the erosion studies, supports their engineering plans. I
>think the regional nature of the study not being applicable to site
>specific engineering must be your way of setting the context for the
>study, so that people would not decide, for example, that because they

>are on a clay-till bluff that they need to be less aggressive about
>erosion protection. That the Army uses this quote as a shield against
>using your conclusions against their plans seems like a misuse to me.
>Is this a correct understanding of the quote?
>
>Also, how does your study fit in with the The Southern Lake Michigan
>Coastal Erosion Study? Is it independent of this other study or a
>sub-section of it? If it is a part of a larger study can you tell me
>how I might obtain a hard copy of the larger study? I see that there
>is a CD Rom available but apparently it is in DOS which may not prove
>to be usable for me. As more background about myself, I am a goldsmith
>and area resident. I am shutting down my retail jewelry store to
>attend law school this fall. I am being represented, pro bono, by the
>Chicago Environmental Law Clinic which is a collaboration between the
>Kent College of Law students and Northwestern's School of Engineering
>students. The Northwestern students found the link to the coastal
>erosion study and I tracked you down based on references to your
>studies in the body of that study.
>
>Thanks for any help you might give me.
>
>Sincerely,
>
>Steven Pollack
>660 Vernon Ave
>Glencoe, IL 60022
>888-300-8031
>

Dr. Randall W. Jibson
U.S. Geological Survey
Box 25046, MS 966
Denver Federal Center
Denver, Colorado 80225
Tel. (303) 273-8577 Fax (303) 273-8600

Steven Pollack

From: Randall W Jibson [jibson@usgs.gov]
Sent: Friday, June 20, 2003 1:29 PM
To: Steven Pollack
Subject: RE: Fort Sheridan data

Steven,

Sorry for the hassle--they were working on some of the servers. Try this link, which should be good for the long term:

http://pubs.usgs.gov/of/2003/ofr-03-231/

Dr. Randall W. Jibson
U.S. Geological Survey
Box 25046, MS 966
Denver Federal Center
Denver, Colorado 80225
Tel. (303) 273-8577 Fax (303) 273-8600

Steven Pollack

From: Randall W Jibson [jibson@usgs.gov]
Sent: Wednesday, October 29, 2003 11:22 AM
To: Steven Pollack
Subject: Re: Fort Sheridan

Steven,

You have a gift for posing difficult questions. Here are some opinions, but they are only that--I am a landslide expert, not really an expert on shoreline recession in general.

My studies showed that on the scale of years to decades, bluff recession was very irregular from point to point along the bluff. The histograms in my reports certainly show that: very erratic recession amounts between various bluff segments. But the fact that the shoreline is regionally very regular in shape and is broadly linear or slightly arcuate means that the local variations in recession somehow even out to produce long-term parallel retreat on the scale of centuries to millennia. In light of this, I would be pretty skeptical about a project designed to protect a short segment of bluff. What ends up happening in such a situation is that the protected bluff segment begins to jut out from the coastline, and then waves begin attacking from the sides and come around behind the protection. It is simply unrealistic to believe you can protect an isolated section of bluff while everything around it is retreating at 25-30 cm/yr.

The regional shore-protection project certainly sounds intriguing. It suggests that they have thought about the processes and realize that localized protection won't work and that a regional approach is needed. I honestly don't know if it would work because I have never seen anything like that actually implemented. I think it would be more likely to be successful than what has been done in the past. I do, however, think that when they look at the costs they may get sticker shock: what they are proposing would be horrendously expensive. Also, it is not a one-time cost. Longshore drift will continually be removing sand from any barrier beaches, and so ongoing beach replenishment will be necessary. While I am uncertain of the technical soundness of what they are proposing, the economics may prove prohibitive.

Slumping of the bluff top is associated only in part with wave attack and beach-erosion processes. A regional offshore shore-protection scheme would certainly help protect the base of the bluff from wave attack, but it would have only limited effects on the stability of the bluff top. The classic cycle goes something like this: waves attack the base of the bluff causing it to become oversteepened. The oversteepened bluff then fails by bluff-top slumping. The slumped material tends to form a buttress at the base of the slope and inhibit additional slumping. If waves attack the bluff and remove the slumped material, the bluff is again destabilized, and further slumping could occur. However, all kinds of slopes that aren't on shorelines fail all the time, so wave attack at the base isn't necessary to destabilize a slope, it just helps accelerate the process. So wave attack exacerbates a pre-existing slope-stability problem. Thus, protecting the bluff from wave attack might decrease the frequency or severity of landslide problems along the bluff, but it would be unlikely to stop those problems completely.

Well, I hope this helps. Let me know if you need any additional info.

Randy Jibson

At 12:49 AM 10/27/2003 -0600, you wrote:
>Dear Randall,
>
>I wanted to get your opinion on something. One of the main points that
>stood out in your report is that the bluffs are recessing in parallel
>manner. My objection to Landfill 7 staying in place is based on this
>observation. The underlying assumption is that significant shoreline
>protection will save one area of the bluff from recession while the
>areas adjacent will keep on recessing. This would create a jut in the
>lake and run contrary to the parallel bluff retreat model. I don't
>believe it will be successful.
>
>There is now talk about a local congressman getting support for a
>bluff-wide shoreline project. What I want to know is if you feel that
>an integrated approach will have a better chance of success than the
>hodge podge of the last 70 years. It is likely that the integrated
>approach will be something to the effect of offshore buffer islands to
>keep the sand in and the waves away from the bluff.
>
>I know you identified several causes of bluff recession, one of them
>being top of bluff shlumping. Given the study you did, will barrier
>islands stop recession if done on a regional basis or is it likely to
>be another false dream like the groin system?
>
>Thanks,
>
>Steven Pollack
>www.familyjeweler.com/fortweb.htm

Dr. Randall W. Jibson
U.S. Geological Survey
Box 25046, MS 966
Denver Federal Center
Denver, Colorado 80225
Tel. (303) 273-8577 Fax (303) 273-8600

Exhibit G

Special Permit Requirements for Ravine and Lake Bluff Property and Other Steeply Sloping Lots in Highland Park, Article XIX STEEP SLOPE ZONE, City of Highland Park, IL Zoning Ordinance, (2002) 10/21/02

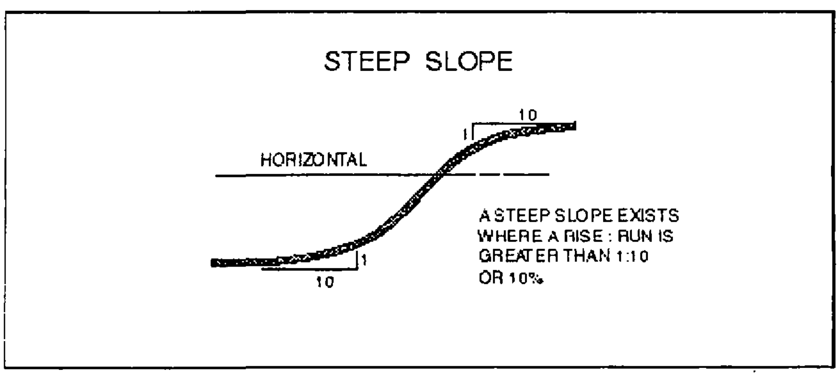
SPECIAL PERMIT REQUIRMENTS FOR RAVINE AND LAKE BLUFF PROPERTY AND OTHER STEEPLY SLOPING LOTS IN HIGHLAND PARK

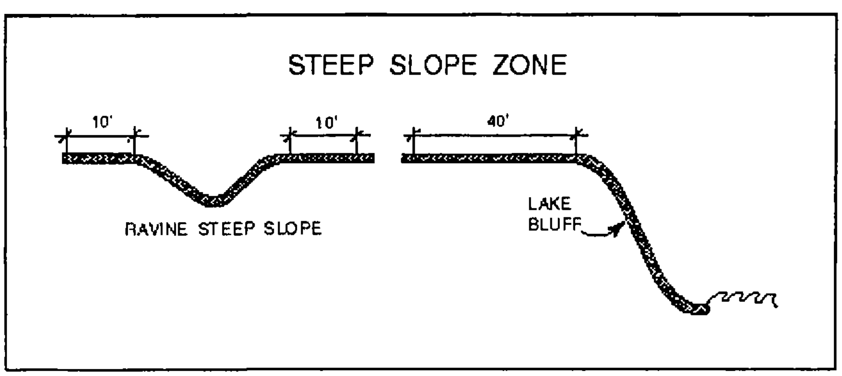
Properties on the ravines and lake bluffs have unique permit and building regulations. These special requirements are designed to protect the ravines and Lake Michigan bluffs from erosion or other soil failures, and also to protect structures built near these sensitive areas. ARTICLE XIX STEEP SLOPE ZONE of the Highland Park Zoning Ordinance contains these special restrictions. The City Building Division staff at (847) 432-0808 can assist you in applying these regulations to your proposed project.

The City of Highland Park Lakefront Commission is also available to assist you, and to make recommendations to the Zoning Board of Appeals regarding variations to ARTICLE XIX that your project may require. Advice from the Lakefront Commission is available at any time, and can help avoid delays or costly changes in projects. Requests to meet with the Lakefront Commission are coordinated through the Commission Liaison in the Planning Division (847) 432-0867.

ARTICLE XIX is revised from time to time. Therefore, you should check with the Building Division or the City website at www.cityhpil.com for the most recent provisions prior to planning your project. The current restrictions are summarized as follows:

1) Building, demolition, and tree removal activities are restricted in the Steep Slope Zone. The Steep Slope Zone includes all land with a 10% or greater slope plus a 10' setback from the top of a ravine slope and a 40' setback from the top of a lake bluff slope. See diagrams below.





2) Special soil investigations and engineering design may be required by the Building Division.
3) In-ground swimming pools must be set back an additional ten feet beyond the Steep Slope Zone.
3) Surface storm runoff must be conveyed either to public storm sewers or to the ravine channel.
4) Dumped debris or natural debris that damages natural vegetation or impedes free flow of water must be removed.
5) Tree removal is regulated, as determined by the City Forester (847) 432-0808.
6) Swimming pool discharge (emptying) must be directed to the sanitary sewer.
7) Damage to the Steep Slope Zone must be repaired.

Exemptions

Within the Steep Slope Zone, the following structures and activities are permitted:

1) Provided that a building permit has been issued, retaining walls and other slope stabilization.
2) Legal, non-conforming structures that have been damaged or demolished may be reconstructed or remodeled, not extending beyond the previous footprint.
3) Mechanical lifts, fences, walkways, steps, bridges, utility lines, subject to approval. Fences must not obstruct the flow of water, and must be set back at least 10 feet from the bottom of the ravine slope.
4) Emergency repairs to prevent an imminent failure, subject to approval.
5) Normal landscape maintenance.
6) Individual accessory structures not exceeding 150 square feet (total structures not exceeding 300 square feet) within the 10 foot setback line from ravines, or 40 feet from the top of bluffs.

Required Submittals with a Building Permit Application

1) Means and Methods of Construction to minimize the disturbance to the Steep Slope Zone.
2) Geotechnical recommendations, Earth Moving Plan, Hydrological Control Plan, and Vegetation Plan as outlined in ARTICLE XIX.

The above is only an overview of the special restrictions and requirements for construction in the Steep Slope Zone. Please study the entire **Zoning Ordinance** and consult with Building Division staff at an early stage in planning your project. Violations of the Zoning Ordinance may result in fines of up to $500 per day.

"Living in a Ravine and Lakefront Community" and "Planting in Ravines", free informational guides about protecting ravine and bluff property, are also available at the Community Development Department at 1150 Half Day Road.

Arnell H.P.
40 feet
Engineering Dept.
Joe Pasquesi

Sec. 150.1902 Statement of Purpose.

(A) The ravine and coastal steep slopes are an inherent natural resource which imparts a unique and substantial character to the City of Highland Park. This unique character has a direct relationship to property values, not only for lots containing or adjacent to ravine and bluff steep slopes, but for lots throughout the City. It is vital to understand that these steep sloped areas are interdependent throughout their reaches. Erosion, slope failures, and loss of vegetation along one portion of a slope can have an adverse impact upon adjacent sloped areas. Because these areas may be abused (intentionally or unintentionally) so as to create conditions which jeopardize property values and the natural ecosystem, appropriate controls are necessary. Thus, it is the intent of this Chapter to ensure that all land use and development controlled by this Chapter:

(1) Protects people and property from the potentially hazardous geological and hydrological conditions characteristic of ravine and bluff areas.

(2) Recognizes and furthers maintenance of stable ecological relationships and minimizes environmental degradation of the land and Lake Michigan.

(3) Recognizes that land should support new structures for a minimum life span of fifty (50) years, and that construction should not contribute to erosion or slope stabilization problems.

(4) Utilizes building techniques within the criteria stipulated in this Chapter.

(B) This zone provides for the reasonable use of steep slope areas and related lands while protecting the public health, safety, and welfare by:

(1) Determining whether certain types of soil conditions exist (such as loose or easily eroded or rocky soils) and utilizing appropriate engineering technology to result in stable slopes during and subsequent to development;

(2) Reducing storm water runoff, soil erosion, and mud slides by minimizing grading and requiring revegetation;

(3) Permitting intensity of development compatible with the natural characteristics of steep slope terrain, such as degree of sloping, soil suitability and existing natural and man-made drainage patterns;

(4) Preserving the scenic quality of the ravine and bluff environment through the retention of dominant steep slopes and ridges in their natural state;

(5) Reducing the physical impact of top of slope and bluff development by encouraging innovative site and architectural design, minimizing grading and requiring restoration of graded areas; and

(6) Reducing cost-efficient public services by encouraging development in the less steeply sloped terrain.

Sec. 150.1903 Aesthetic and Safety Control of Steep Slopes

As set forth above, this Article has as its purpose protection of public health and safety by adopting and attempting to prevent erosion and protecting the aesthetics of ravines and bluffs through the regulation and management of the steep slope zone. It is not the intent of this Article to remove areas of use nor is it the purpose of this Article to increase development costs.

(A) Except as set forth in this Article, no structures shall be constructed in a Steep Slope Zone. In addition, whenever there is construction upon property abutting a Steep Slope Zone, a fence will be erected temporarily along the top edge of the steep slope, during any construction and/or demolition activity upon such property.

(B) Basic Technical Standards. All land use and development controlled by this Article shall be judged by the application of the following basic standards of landscape planning, soil mechanics engineering, hydrology, geology, environmental design and architecture. These standards are supplemented elsewhere in this Article.

(1) Planning development to recognize and fit the natural topography, soils, geology, hydrology and other existing conditions on the proposed sites.

(2) Orienting development so that earth moving, landscaping and other site preparation is kept to an absolute minimum.

(3) Preserving and enhancing the landscape through minimized disruption of natural terrain and existing vegetation.

(4) Minimizing disruption or alteration of natural drainage ways.

(5) Minimizing the time in which areas are bare and exposed.

(6) Minimizing the amount of impervious surface to be placed on the tableland adjacent to steep slopes.

(7) Designing structures so that significant weight is not oriented toward the top edge of steep slopes.

Exhibit H

Steep Slope Ordinance, Sec. 46-15 City of Lake Forest, IL, (2004)

THE CITY OF LAKE FOREST

CHARTERED 1861

City Services

Community

Steep Slope Ordinance

Download a copy of this Ordinance:

Steep Slope Ordinance (26k - 2 pages)

TABLE OF CONTENTS

Sec. 46-15. Steep Slope Ordinance

(A) PURPOSE. TOP

The provisions contained herein are adopted to protect public and private property destruction resulting from natural erosion processes occurring within the ravines a the shore of Lake Michigan, or abnormal or accelerated ravine and bluff erosion re development and construction activities occurring on adjacent or nearby propertie: the fragile ravine and bluff ecosystem from unwarranted damage or destruction ca development and construction activities.

(B) APPLICABILITY. TOP

The provisions contained herein shall apply to all land development and constructi all properties abutting ravines and bluffs as delineated by hashed lines (or shaded A, a copy of which is attached hereto and made a part hereof.

(C) REQUIREMENTS AND RESTRICTIONS. TOP

(1) Building Setbacks:

(a) From Ravines

All building construction shall be on Table Land, but in no case shall structure or building foundation be located closer than twenty (20) fe to the Ravine Area.

(b) From Bluffs

All building construction shall be on Table Land, but in no case shall structure or building foundation be located closer than seventy-five (7 feet to the Bluff Area.

(2) Construction Activity:

(a) Adjacent to Ravines

All construction activity; i.e., grading, excavating, filling, terracing, tre removal, stockpiling of excavated material, is prohibited within twenty (20) feet of the Ravine Area, except as may be necessary to provide drainage improvements, as may be approved and/or required by the City Engineer.

(b) Adjacent to Bluffs

All construction activity; i.e., grading, excavating, filling, terracing, tre removal, stockpiling of excavated material, is prohibited within fifty (5 feet of the Bluff Edge, except as may be necessary to provide site drainage improvements, as may be approved and/or required by the City Engineer.

(3) Site Landscaping:

Upon completion of construction activities, minimal grading and clearing of vegetation may be allowed within the Bluff or Ravine Area in order to install vegetation and lawn landscaping. However, no such grading, clearing or lar will be permitted within twenty (20) feet of the Ravine Edge or within fifty (5(the Bluff Edge.

(4) Site Drainage:

A Site Grading Permit, approved by the City Engineer, shall be required bef site grading work may take place. Measures shall be required to control sto runoff from impervious areas, lawns, and footing drains. Wherever feasible, runoff shall be collected and carried to established storm drainage facilities away from the Ravine or Bluff Area as the case may be. If discharge into ar established storm drainage structure is not feasible, drainage shall be colle discharged into the ravine channel or from the top of the bluff to its base in which minimizes disruption of the ravine or bluff slope and potential erosion bluff toe or the ravine toe and channel, subject to the specific approval of th Engineer.

(5) Channel Modification:

Where the City Engineer finds that an unstable ravine or bluff slope or toe e likely, or where the configuration of the ravine channel has resulted in erosi suggests the probability of future erosion, channel, toe or slope stabilization measures may be required by the City Engineer.

(6) Required Information:

Prior to submission to the City of a request for Tentative Approval of a Plat Subdivision or review of an Application for a Building Permit, the owner or a the owner of property, subject to this Section, shall submit to the City Engin applicable site information, including but not limited to topography, existing vegetation, ravine and/or bluff conditions (including establishment of the lim Ravine or Bluff Area), geological and soil conditions, proposed plans for lan and lawn installation, and such other information as may be deemed neces the City Engineer in order to implement the policy and requirements of this

(7) Definitions:

a.) RAVINE AREA - The Ravine Area shall include all property withir adjacent to a ravine beginning at the point of intersection of a line wit the table land, said line extending from the toe of the slope upward a vertical angle of twenty-two (22) degrees.

b.) RAVINE EDGE - That point on the ravine side of the table land where the slope of the land first exceeds ten (10) percent.

c.) TABLE LAND - Land where the slope in any direction does not exceed ten (10) percent.

d.) TOE OF SLOPE - The toe of the ravine or bluff slope is that point the ravine or bluff where the slope is less than twenty-two (22) degre or where the slope reverses directions. On compound slopes where there may be more than one possible toe location, the controlling poi shall be whichever toe location provides the greater ravine or bluff ar

(D) REVIEW GUIDELINES AND APPROVAL PROCEDURES. TOP

(1) The City Surveyor and Engineer may approve encroachments into the b ravine setback area for the construction of landscape features, auxiliary bui (slab foundation), bridges, wood decks or other similar facilities, if the City S and Engineer finds that:

(a) The proposed construction is appropriate only for requested local

(b) The proposed construction will have no significant impact on the ravine or bluff area.

(c) The proposed construction is of relatively low value, except for ite related to ravines such as vehicular bridges.

(2) The Zoning Board of Appeals may consider variations from the requirem this section for construction of habitable facilities such as room additions or residences, and construction of significant auxiliary buildings. In considering variations, the following guidelines, in addition to the four findings of fact as in Section 46-21-(F)-(3), shall be considered:

(a) Construction in the twenty (20) foot setback for the twenty-two (2: degree slope intersect could be recommended if there exists adequa toe of slope improvements.

(b) Construction in the twenty-two (22) degree slope angle could be recommended if there exists adequate slope or other improvements effectively increase the stable slope angle.

(c) Variation from building on land that exceeds ten (10) percent slop but is outside of the twenty (20) foot setback from the twenty-two (22 degree slope angle could be recommended if entire slope shows no indication of instability.

(d) Variation from any restriction could be recommended if the requested construction is less nonconforming than the existing residence and the ravine or bluff slope does not show any indication instability; or if the applicant submits evidence based on current geotechnical engineering practices such as the Simplified Bishop Method of stability analysis whereby variables of soil shear strength, ground water level, unit weight of soil and slope angles are consider(which result in the determination that the particular slope is stable at angle greater than twenty (22) degrees.

Exhibit I

Permits for Breakwater Structure, R. Fileccia to Colleen Reilly, ARPA email, (December 16, 1997)

ESSAGE Dated: 12/15/97 at 14:37
ıbject: Permits for the Breakwater Structure. Contents: 3
ender: rfileccia / inet-shar
DDT1=RFC-822; DDV1=rfileccia@smtp.orl.usace.army.mil;

art 1

ROM: rfileccia / inet-shar
DDT1=RFC-822; DDV1=rfileccia@smtp.orl.usace.army.mil;

TO: reillyc / inet-shar
DDT1=RFC-822; DDV1=reillyc;

rt 2

ARPA MESSAGE HEADER

rt 3

lleen: I asked Ray Haynes of Planning Division to write up his justification to why he felt we did not need a permit. His response is as follows:

e recommended plan, i.e., the construction of a breakwater & groins with sand fill, does not require a permit under Section 404 of the Clean Water Act or ction 10 of the Rivers and Harbors Act of 1899. The landfill remediation quires protection of the bluff to preserve its design capabilities and as such ıld not operate efficively but for the provision of subject action. The eakwater is the only feasible method of providing 30+ year protection of the e and, as such, becomes integral to the site; the one not capable of filling its function without the other. To assume otherwisw is to build the eakwater with no CERCLA purpose and hence, making it a separable item of ıstruction requiring full NEPA, CWA, etc compliance as a distinct federal oject.

Find NCP citation

Preamble 300.400(e)

Section 121(e)

"on site" in 300.400(e)(1) include the "areal extent of contamination + all suitable areas in very close proximity to the contamination necessary for implementation of the response action".

Exhibit J

Panel 17097C0283 F, Flood Insurance Rate Map, Lake County, Illinois, Federal Emergency Management Agency, (Sept. 3, 1997)

Limited copies,
not included

Exhibit K

Explanation of 100-Year Flood Zone Designation for Fort Sheridan, email from David Schein, Senior Program Manager, Department of Homeland Security, Federal Emergency Management Agency, Region V, (May 19, 2003)

Steven Pollack

From: Steven Pollack [digitaljeweler@attbi.com]
Sent: Friday, May 09, 2003 12:21 AM
To: jeanne.millin@fema.gov
Subject: Fort Sheridan Flood Maps

Dear Ms. Millin:

I am studying issues at Fort Sheridan regarding shoreline erosion and the suitability of leaving Landfill 7 in place along the shore of Lake Michigan.

I ordered FEMA floodplain maps a few years ago and they show the shoreline of southern Lake Michigan as a regulatory 100 year floodplain. The panel is 17097CO283F. When I brought this up to the Base Environmental Coordinator she denied it(which I took as an indication that the landfill being in a regulatory 100 year floodplain is a significant issue). Others who I have told this to have raised their eyebrows at this possibility and then there was an incredulity that the shoreline is actually zoned as such.

I would think it is in the purview of the FEMA to make such a determination. Can you comment on these maps showing the shoreline as a 100 year regulatory floodplain and if not can you direct me to the person at FEMA that could answer this for me?

Thanks,

Steven Pollack
P.O. Box 1370
Highland Park, IL 60035
www.familyjeweler.com/fortweb.htm

Steven Pollack

From: Millin, Jeanne [Jeanne.Millin@dhs.gov]
Sent: Monday, May 12, 2003 8:13 AM
To: Schein, David
Cc: 'digitaljeweler@attbi.com'
Subject: RE: Fort Sheridan Flood Maps

David:
For your response.
Jeanne

> -----Original Message-----
> From: Steven Pollack [mailto:digitaljeweler@attbi.com]
> Sent: Friday, May 09, 2003 00:21
> To: jeanne.millin@fema.gov
> Subject: Fort Sheridan Flood Maps
>
> Dear Ms. Millin:
>
> I am studying issues at Fort Sheridan regarding shoreline erosion and
> the suitability of leaving Landfill 7 in place along the shore of Lake
> Michigan.
>
> I ordered FEMA floodplain maps a few years ago and they show the
> shoreline of southern Lake Michigan as a regulatory 100 year
> floodplain. The panel is 17097C0283F. When I brought this up to the
> Base Environmental Coordinator she denied it(which I took as an
> indication that the landfill being in a regulatory 100 year floodplain
> is a significant issue). Others who I have told this to have raised
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>
> I would think it is in the purview of the FEMA to make such a
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> a 100 year regulatory floodplain and if not can you direct me to the
> person at FEMA that could answer this for me?
>
> Thanks,
>
> Steven Pollack
> P.O. Box 1370
> Highland Park, IL 60035
> www.familyjeweler.com/fortweb.htm
>

Steven Pollack

From: Schein, David [David.Schein@dhs.gov]
Sent: Monday, May 19, 2003 8:24 AM
To: 'themissinglink@eznetinc.com'
Cc: Millin, Jeanne; Parisi, Vincent; Traeger, Lee
Subject: Lake Michigan Floodplain

Mr. Pollack:

This agency, in cooperation with the U.S. Army Corps of Engineers (Open Coast Flood Levels,1988) has determined the 1 percent annual chance flood for the western shore of Lake Michigan to be 584 feet above mean sea level. This elevation does not include wave set-up. This floodplain is depicted on all of our floodplain maps for North Shore communities but we have not always added the numeric elevation to all the maps. We typically did not map federal land so the military installation may not have a floodplain shown on the old maps. However, the new Lake County county-wide Flood Insurance Rate Map does show this floodplain. As you are probably aware, the shoreline rises rapidly from the beach at Fort Sheridan. Lake Michigan is at a cyclical low elevation at present, exposing more beach than in an average year. But typically, the so-called 100-year floodplain is not more than six feet above mean water level. I hope this is useful to you and if you have further questions, please contact Vincent Parisi, Natural Hazards Program Specialist, on 312.408.5597. Thank you.

David Schein, Senior Program Manager
Dept.of Homeland Security
Federal Emergency Management Agency, Region V
312.408.5539
david.schein@dhs.gov

Exhibit L

Assessment of Water Resources at Fort Sheridan Referencing 100-Year Floodplain, U.S. EPA Website, (June 20, 1997)

S.3.4 Water Resources

Random things from US EPA website

S.3.4.1 Groundwater

In most of Lake County, wells are the main sources of water. However, Fort Sheridan and the surrounding communities draw water from Lake Michigan because glacial deposits underlying the area are poor sources of potable water. The water table is generally three to five yards below the surface. The water table slopes to the east, except in the vicinity of the Fort Sheridan ravines, where the direction is assumed to be toward the ravines.

Historical records coupled with some subsurface excavations indicate that coal ash and other debris have been buried in the western end of some ravines. This fill does not appear to be toxic, and available data indicate that contaminants are not migrating beyond the installation boundaries. The potential for migration of contaminants to the aquifer is unlikely due to a low permeability rate and also to the ion exchange capacities of the soil which tend to remove contaminants from leachates (U.S. Army Corps of Engineers, 1982a).

A hydrologic and subsurface exploration (performed by Soil Test Services of Northbrook, Illinois in 1978) indicated that groundwater quality at Fort Sheridan meets the requirements for maximum allowable concentrations of pollutants set forth by the State of Illinois Pollution Control Board. Table 3 S-1 summarizes the results of the sampling.

Table 3 S-1

GROUNDWATER SAMPLE ANALYSIS

Constituent		Monitoring Wells (1) B-1	B-2	
pH (pH units)		7.90	7.88	
Chloride		7.80	8.25	1
Iron (Total)		4.75	1.10	7
Dissolved Solids		390.0	286.0	70
Sulfate	93.2	40.8	295.0	
C.O.D.	71.4	63.5	194.4	

(1) Samples taken on August 31, 1978.

- All data have units of mg/l unless otherwise noted.

Source: U.S. Army Corps of Engineers, 1982a.

S.3.4.2 Surface Water

Fort Sheridan and the surrounding communities all lie within the 34,100-acre Lake Michigan Basin-North drainage area. This drainage basin is a narrow strip along the Lake Michigan coastline in Lake County which includes 31 miles of shoreline from the Cook County border northward to the Wisconsin state line. The basin width ranges from approximately one mile at the southern boundary to three miles at its northern boundary. Within the Fort Sheridan boundaries, there are six ravines that drain surface water from the area into Lake Michigan. The general configuration of these ravines is illustrated on Figure 3S-1.

The only existing impoundment at Fort Sheridan is the Rod and Gun Club Pond located near the northeast corner of the installation (See Figure 3S-1). This impoundment has a surface area of approximately one acre and is 15 feet deep at maximum pool elevation. Constructed in 1967 and stocked with largemouth bass, bluegill and channel catfish, the pond is fed by a groundwater well and has no watershed. Fort Sheridan also has one swimming beach which is not open to the public, but is used by Fort Sheridan personnel and their families.

Lake Michigan is immediately adjacent to Fort Sheridan. Within the lake, there are two "zones", a nearshore zone, and an offshore zone that begins about five or ten miles from shore. The two zones are the result of differences in water temperature and density. There is little mixing of nearshore and offshore waters, so that pollutants discharged into nearshore waters tend to remain close to shore. Winds and bottom topography also restrict the offshore movement of surface waters and inhibit the spread of nearshore pollution. Annual and seasonal variations in

Figure 3S-1

water levels depend primarily on changes in precipitation and evaporation. Seasonal water levels generally are highest in mid-summer and lowest in mid to late winter.

S.3.4.3 Floodplains/Wetlands

Floodplains. The Flood Insurance Rate Map for the Cities of Lake Forest and Highland Park, Illinois, Community Panel Numbers 170374 0006 C and 170367 0002 B, respectively, issued by the Federal Emergency Management Agency, effective date February 18, 1981 and November 5, 1980, respectively, indicate that the shoreline of Fort Sheridan is zoned within a regulatory floodplain.

This is based on a 100 year flood elevation of 584 feet above mean sea level. No Flood Insurance Rate Map for the Town of Highwood (which includes the central portion of Fort Sheridan) was printed, indicating that no floodplains exist. However, the existence of a shoreline zone on either side of the area would indicate that a similar zone is in fact present along the entire Lake Michigan frontage. A report entitled Flooding in the Highland Park Quadrangle, Illinois, was prepared for the Northeastern Illinois Planning Commission by the U.S. Geological Survey in 1963. This report indicates that there are no other floodplain areas on or adjacent to Fort Sheridan.

Wetlands. Wetland maps prepared by the U.S. Department of the Interior (1981), Fish and Wildlife Service, in conjunction with the Illinois Department of Conservation, show a total of four wetland areas on Fort Sheridan (See Figure 3S-2). No attempt was made to delineate wetlands using the Federal Manual for Identifying and Delineating Jurisdictional Wetlands.

Based on the Fish and Wildlife Service maps, three wetlands are located along the east side of the installation covering approximately 3,900 linear feet of lake shore with 9.9 acres or 430,000 square feet in area. The only other wetland, commonly known as the fish pond, located between Jane's and Hutchinson Ravines, is approximately one acre. The two wetland categories on the installation are classified as Lacustrine-Littoral-Unconsolidated Shore (L2USJ) and Palustrine-Open Water (POWGx) (scientific classification: system-subsystem-class).

S.3.7.6 Solid Waste Disposal

All solid waste currently generated at Fort Sheridan is collected by a private contractor and disposed of at a facility outside the installation. As shown on Figure 3S-8, eight solid waste landfill sites have been identified at Fort Sheridan (U.S. Army Corps of Engineers, 1987a). Five of the disposal areas were located in or adjacent to the ravines which traverse the installation from west to east, or along the areas fronting Lake Michigan. Discussions of each of the landfill areas shown in Figure 3S-8 are provided below.

Landfill No. 1. This approximately three acre landfill is mostly covered by concrete and asphalt for use as a vehicle parking and storage area. It was operated from 1940 to the early 1950s and received general refuse. Prior to completion of soil cover, open burning was conducted at this site. Available information does not indicate that hazardous materials were disposed of at this landfill.

Landfill No. 2. This former landfill area (in use prior to WWII) occupies approximately three acres. Excavations in this area have uncovered small pieces of coal and cinders and some reports indicate the disposal of ammunition by detonation on site. There is no record of hazardous waste disposal at this landfill. The site is currently capped with soil, and no cracks were observed in the cover during an installation assessment update completed in May of 1987 (Figure 3S-8 U.S. Army Corps of Engineers 1987a). No leachates were observed along the end of the landfill fronting the Lake Michigan shoreline.

Landfill No. 3. Landfill No. 3 was operated prior to 1947 and received industrial and domestic refuse. Open burning was practiced at this location. Available information does not confirm that hazardous wastes were disposed of at the area; however, the industrial wastes disposed of at the area could have included POL and other potentially hazardous items. The approximately 2.5 acre area is now under an asphalt parking lot.

Landfill No. 4. Landfill No. 4 is a one acre site located immediately west of Landfill No. 3 and between Bldgs. 89 and 66. Available information indicates construction rubble was the only material disposed of at this location. This location was used as a disposal area during the mid-1960s and is visible on a 1967 aerial photograph of the installation.

Landfill No. 5. Refuse disposed of at this location has included cinders, bottles, and construction rubble. Excavations in the area have uncovered Coca-Cola bottles dating back to the early 1900s. The location was used for the disposal of construction rubble in the mid-1960s. Buildings 378 and 133 are constructed on the landfill area. Available information does not indicate disposal of hazardous materials.

Landfill No. 6. Landfill No. 6 is the disposal area located in Wells Ravine west of Patten Road. This landfill was used in the 1960s and was visible in 1967 aerial photographs. Reports indicate disposal of industrial and domestic wastes and building demolition debris. Available information does not include a record of hazardous material disposal; however, some solvents and other POL products are probably buried at this site. Two storm drains underlie Landfill No. 6 and enter Lake Michigan at the discharge end. These drains provide potential conduits for any leachate to migrate into Lake Michigan if infiltration occurs. If leachate is formed and does not infiltrate the storm drain, it would migrate through Landfill No. 7 toward Lake Michigan.

Landfill No. 7. Landfill No. 7, also known as the Wells Ravine Landfill, is located east of Patten Road in the southern part of the installation. The landfill is approximately 7.9 acres in size. The original depth of the Ravine is estimated to be 35 feet.

Fill material included domestic, general, industrial, and hospital wastes. Open burning was practiced at this location prior to 1970. The open-burning procedure was to dig a trench at the base of the landfill near the lakeshore and burn wastes in that trench. Coal ash from the heating plant was often used as temporary cover material.

Materials disposed of at this landfill include waste oil, solvents, paint, paint thinner, paint stripper, cleaning compounds, hospital and veterinary wastes, photographic chemicals, ammunition boxes treated with pentachlorophenol, radioactive instrumentation, sewage treatment plant sludge, incinerator ash, building debris, and domestic and office refuse. (ANL, 1989.) Landfill No. 8. Landfill No. 8 is located on the southern end of the installation between the housing area and the shoreline of Lake Michigan. The dates of operation of this fill area are unknown; however, it is visible in a 1952 aerial photograph. The area had been seeded and contoured in the 1962 and subsequent aerial photographs. The area is approximately three acres in size. No information is available concerning the types of materials buried at the site. During an onsite assessment by USATHAMA, broken glass, coal cinders, and other small items of construction rubble were observed at the area. No leachate was observed at the landfill.

SC.4.4 Water Resources (Environmental Consequences)

SC.4.4.1Groundwater

Several old landfills have been identified on the site. The composition of these landfills consist variably of non-toxic components such as coal ash and other debris. However, two of these landfill sites (#3 and #6) may contain some hazardous substances. The potential for migration of unidentified contaminants in the soil to the aquifer is unlikely due in part to the low permeability rate and also to the ion exchange capacities of the soil.

As previously discussed in the soil resources section (SC.4.3.4), all potentially hazardous materials and wastes will be removed from the installation under the provisions of the Defense Department's Installation Restoration Program (IRP). Because current operations have not been identified as sources of contamination, this impact, although beneficial, is not considered to be significant.

As described in the affected environment section, Fort Sheridan and the surrounding communities use Lake Michigan as their water supply source due to the naturally poor quality of the groundwater in the area. Consequently, no impacts to groundwater quality or quantity are anticipated with closure activities.

SC.4.4.2Surface Water

The potential for degradation in surface water quality at Fort Sheridan will effectively be reduced as a result the closure action in that a lower incidence of accidental release of petroleum products or other hazardous substances will occur as a result of decreased military operations. However, operations will continue in the Reserve Component Area. Each of the southern alternatives for the Reserve Component Area (plans A,B, C and G) are well removed and isolated from surface water resources (ravines and ponds). Therefore, impacts from accidental spills or pollutants in surface water runoff will be relatively minor as spills typically are cleaned up prior to their reaching any surface water resource.

The nearness of Reserve Component Area plan D to Jane's Ravine and its downgradient surface water resources (e.g., Lake Michigan) increases the potential for impact. Initial construction activities (e.g., buildings, utility systems, roads) followed by a higher intensity of use in this primarily undeveloped area will increase the potential for siltation and sedimentation. In addition, the incidence of accidental spills and the subsequent migration of contaminants to surface water resources may also increase. Potential impacts to surface water resources may be reduced by providing for adequate erosion and sedimentation controls and by providing for spill prevention planning and control.

Exceedences in effluent standards of the North Shore Sanitary District have been recorded. Contributing factors to these violations include the overall inefficiencies of the system at Fort Sheridan and past overloading of the treatment facility during periods of heavy rainfall. Recent improvements and repairs in the collection system at Fort Sheridan have however, reduced the relative impact of Fort Sheridan on regional water quality. Closure actions will have no impact on this condition.

SC.4.4.3Floodplains/Wetlands/Coastal Zones

As discussed in Section S.3.4.3 floodplains and wetlands in the project area are predominantly restricted to the Lake Michigan shore and beach areas. An additional small palustrine wetland is also represented by the fish pond at the north end of the site.

The potential for negative impacts on area floodplains and wetlands will be reduced as a result of the closure action since transfer of the military mission will preclude the need for development of additional facilities and related infrastructure which could add to the quantity of surface water runoff. However, it is anticipated that new construction projects will be completed within the Reserve Component Area to be maintained as part of the closure action.

Construction activities at potential Reserve Component Area plans A,B, C or G (southern area plans) are not expected to have any significant direct or indirect impact on floodplains, wetland resources or coastal zones in the project area. This is due to the fact that building rehabilitation and/or new construction would occur a considerable distance from floodplain or wetland resources and would be limited to the existing, previously disturbed cantonment area. If Reserve Component Area plan D is selected (northern plan) some potential exists for an indirect impact on Jane's Ravine and its associated coastal floodplain area. This conclusion is based on the fact that new construction will occur on previously undeveloped areas directly adjacent to the western end of Jane's Ravine. This impact could be mitigated through careful site design including adequate attention to drainage details and provision for on-site retention of stormwater runoff.

RTK NET MASTER AREA REPORT

search used- Zip Code: ALL
City: FORT SHERIDAN
State: IL
Year: ALL

This search was taken from RTK NET's (the Right-To-Know Network)'s copies of various EPA databases. RTK NET is run by OMB Watch and Unison Institute at 1742 Connecticut Ave., NW, Washington DC, 20009 - Phone: 202-234-8494
The search was done on 06/16/1997.

If you don't see the words *END OF REPORT* at the end of this search, then this Web search didn't complete -- back up and try it again.

# of CERCLA sites found : 1
# of ERNS reports found : 5
# of FINDS facilities found: 2
# of PCS permits found : 1
# of RCRIS handlers found : 1
Mailing as well as facility addresses in the above databases were searched.

RCRIS DATA

RCRIS (RCRA Information System) data shows hazardous waste permits for generators, receivers, and transporters of hazardous waste. The first line of each record below shows the handler (facility) name, city, and state.

US ARMY FORT SHERIDAN COMMANDER FORT SHERIDAN IL
Generator Status : Large Quantity Generator (LQG)
Treatment, Storage & Disposal Status: Treatment/Storage
Number of permits : 1 Number of recorded violations to date: 13

PCS DATA

PCS (Permit Compliance System) is EPA's database of water pollution permits. Only the 1992 data year is currently available. The first line of each record below shows the PCS legal facility name, system-generated city & state, and NPDES ID. Any non-'C' compliance flag indicates that the facility was in noncompliance.

FORT SHERIDAN-NPR FORT SHERIDAN IL IL0033014
Compliance Flags: Major facility:

CERCLIS DATA

The CERCLA List of sites is a list of potential and actual sites that might have to be cleaned up under Superfund. All currently known sites are in this database, including NPL sites. The first line of each record below shows the site name, city, state, and EPA ID.

US ARMY FORT SHERIDAN FORT SHERIDAN IL IL221002083

NPL Status: NOT ON NPL
Discovery Date: 08/01/1980

ERNS DATA

ERNS (Emergency Response Notification System) data are records of phone calls reporting toxic releases and spills to the National Response Center. Data is currently available for 1987-1996. The first line of each record below shows the name of the discharging organization (if any could be identified) plus the city, state and reporting year of the spill.

425TH TRANSPORT. BRIGADE	BARKSDALE AFB		LA	1993
Discharger located in: FORT SHERIDAN		IL		
1st chemical: JET FUEL: JP-4		Lbs released: 6,700		
USA - FORT SHERIDAN	FORT SHERIDAN		IL	1993
1st chemical: UNKNOWN OIL		Lbs released: 83		
USA- RESERVE COMMAND 86TH	FORT SHERIDAN		IL	1994
Discharger located in: FOREST PARK		IL		
1st chemical: OIL, FUEL: NO. 1-D		Lbs released: 700		
USA-86TH RESERVE COMMAND	FORT SHERIDAN		IL	1994
Discharger located in: FOREST PARK		IL		
1st chemical: UNKNOWN OIL		Lbs released: 0		
USA-FORT SHERIDAN	FORT SHERIDAN		IL	1994
Discharger located in: FORT MCCOY		WI		
1st chemical: GASOLINE: AUTOMOTIVE (4.23G PB/G		Lbs released: 0		

FINDS DATA

The FINDS Facility Index System is a list of all facilities in most EPA facility-specific databases. It is used to determine unique facilities and assign EPA IDs. The first line of each record below shows the facility name, city, state, and EPA ID.

US ARMY RESERVE CTR	FORT SHERIDAN	IL	IL0000594929
USARMY FT SHERIDAN	FORT SHERIDAN	IL	IL8214020838

Exhibit M

Review of Army Request for Concurrence With Deviations from Interim Landfill Decision and Design Documents, Letter from W. Owen Thompson, Remedial Project Manager, U.S. EPA, to Victor Bonilla, Forces Command, Department of the Army, (May 5, 2003)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, ILLINOIS 60604

REPLY TO THE ATTENTION OF: SR-6J

May 5, 2003

Headquarters, Forces Command
Deputy Chief of Staff, G1
Attn: AFG1-BC (Victor Bonilla)
Ft. Sheridan BRAC Environmental Coordinator (BEC)
1777 Hardee Avenue, SW
Ft. McPherson, GA 30330-1062

RE: Revised Puncture Calculations
Response to Illinois EPA March 4, 2003 Letter
Rock-Picking Field Modification, Hard Hat Services, Inc. (HHSI)
1) March 18, 2003 Letter to FORSCOM
2) April 1, 2003 Revised Calculations Memorandum
Transmitted by your letter dated April 18, 2003

Dear Mr. Bonilla:

We have completed our review of the subject documents. Your letter specifically requests U.S. EPA concurrence with HHSI's conclusion:

> *"HHSI, as certifying engineer, strongly believes that the cover soils that have been placed are acceptable and will not affect the performance of the engineered cap, as designed."*

Your letter also states that the attachments provide technical support that the unscreened cover soils "meet the spirit of the design." Spirit of the Design (SOD) is the performance objective that the Army has been using to approve design changes under the GFPR contracting approach at Ft. Sheridan (reference your September 19, 2002 email, transmitting previously-constructed design changes to U.S. EPA and Illinois EPA for our information).

Let me begin with a few general observations on design changes:

1) U.S. EPA takes a very literal approach in evaluating whether a project has been built as designed. We have noted that when the Army Corps of Engineers was managing this project, it followed a similar policy. Our published guidance for Evaluation of Federal Agency OPS Demonstrations, which in this instance FORSCOM has decided not to use, discusses the design evaluation approach that U.S. EPA uses. The

"spirit of the design" approach is not mentioned in the OPS guidance, defined in the NCP, nor any other Army or EPA published guidance we are aware of.

2) U.S. EPA will not retroactively approve design changes at this site. This site is not on the NPL, and the Army has made it very clear that although they would like concurrence, U.S. EPA approval has not been considered necessary for the GFPR contractor to achieve "regulatory closure". Since we cannot regulate what your contractor is doing, it is essential for you to get our prior concurrence with design changes, and not just defend your decisions after construction is complete. If we were the lead agency on this CERCLA site, we would not let our contractors make these sorts of unilateral design changes. We don't think that the GFPR contractor should be held to a lower standard just because they work for the Army.

The 2" maximum rock diameter is already 64 times less conservative (by volume) than DoD's current Uniform Facilities Guide Specification for Clay Landfill Barriers. So there is no reason, other than cost, why clay having any large rocks at all should have been trucked into Ft. Sheridan. The design change originally proposed by HHSI (and rejected by Parsons) to allow placement of 8" boulders was 4,100 times less conservative than the current guide spec and even HHSI states that there is no way to state with certainty that large boulders are not present.

3) Illinois EPA is the lead regulatory agency at Ft. Sheridan. Your letter essentially asks U.S. EPA to pass judgement on the opinion of a State-licensed Professional Engineer. The written opinion of the Army's design/oversight engineer could not be sighted in the package we received. Does the Army concur with HHSI's conclusion? The efficacy of permitting large rocks to remain in the cap is primarily a matter of compliance with State landfill regulations (ARARs), and we accordingly shall defer to Illinois EPA's determination. We encourage the Army to take the State's comments seriously and work to promptly resolve them.

U.S. EPA concurs that it is unlikely that any rocks that are present have physically punctured the composite membrane. Apparently, rock penetration is the sole criterion that the Army is using to determine cover soil acceptability and cap performance, and thereby meet the "spirit of the design" for purposes of achieving the GFPR contract performance objective.

However, when evaluating risk under CERCLA, U.S. EPA must go beyond the SOD "faith-based approach." We can't ignore the fact that an unknown number and size of pothole-like depressions exist in the membrane surface, created by the remaining rock and clay boulders in the cover. These depressions are probably holding water, and have already been through a year of very severe ground-freezing conditions (lack of snow cover). This raises a number of uncertainties.

-HHSI and Kemron assure us that the cover materials are "warranted", but what do these warranties provide for (e.g. what proof of failure is necessary) and how meaningful are these warranties to the overall cap performance?

-How significant is the thinning of the bentonite in the GCL layer, under the potholes? Wouldn't this create a point of high permeability at the exact spot where the cover is permanently wet?

-What is the cumulative effect of these depressions on site drainage,

especially in the flatter areas of Landfill 6?
-A big concern for gas emissions; what sorts of stresses have been placed on the liner membrane and seams by these depressions? If there are leaks, how significant is the risk they represent?
-What sorts of preferential pathways are created for water and gas migration by the presence of boulders in the cover soils?

We realize that it would be difficult or impossible to evaluate these qualitative concerns from an engineering perspective. This is probably why the design engineer (and DoD in its 1999 UFGS) didn't think it was a good idea to permit large rocks in cover soils in the first place.

Therefore, we regret that we cannot concur with the HHSI's conclusions at this time.

On March 25, 2003, almost six weeks ago, the Ft. Sheridan BRAC Cleanup Team met at our offices with U.S. EPA and Illinois EPA management and several Army contractors. The purpose of the meeting was to discuss U.S. EPA's future role in the Ft. Sheridan GFPR remediation project. At the end of the meeting, it was understood and discussed that the Army would prepare a letter which would spell out DoD's regulatory approval expectations from U.S. EPA for the remainder of the project. To date we have not received this letter from the Army.

Accordingly, these comments should be considered a response to a voluntary advisory opinion request from the Army. Even though it appears from your contractor's actions that the Army has not considered U.S. EPA approval to be required up to now, our comment letter might assist you in determining what additional work might be necessary to get that approval (e.g., get the site NFRAPed or ready for the Navy to transfer). We trust that your forthcoming letter will explain exactly what the Army, Navy and Army Reserve are expecting from U.S. EPA.

I can be reached at 312 886-4843 if you have any questions.

Sincerely yours,

/S/

W. Owen Thompson
Remedial Project Manager
Federal Facilities Response Section

cc: Brian Conrath, Illinois EPA
soft cc: (electronic only)
Kurt Zaccharias, U.S. Army Reserve Support Command
Dan Fleming, Navy Great Lakes EFA Midwest
Mark Shultz, Navy Great Lakes EFA Midwest
Kurt Thomsen, Ph.D., Versar, Inc.
Gary Schafer, Chief, EPA Region 5 FFRS
Bill Hopkins, TechLaw, Inc.

Exhibit N

Suggestions for Gaining U.S. EPA Concurrence at Landfill 6 & 7, Letter from W. Owen Thompson, Remedial Project Manager, U.S. EPA, to Victor Bonilla, Forces Command, Department of the Army, (Sep. 25, 2003)

5.113 2

Attn: Tracy
FROM: US ARMY AFO (Shoki)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, ILLINOIS 60604

REPLY TO THE ATTENTION OF: SR-6J

September 25, 2003

Headquarters, Forces Command
Deputy Chief of Staff, G1
Attn: AFGI-BC (Victor Bonilla)
Ft. Sheridan BRAC Environmental Coordinator (BEC)
1777 Hardee Avenue, SW
Ft. McPherson, GA 30330-1062

RE: Suggestions for Facilitating U.S. EPA Concurrence
Landfills 6&7 CERCLA Remedial Action
U.S. Army Ft. Sheridan, Illinois
CERCLIS Site ID #IL2210020838

Dear Mr. Bonilla:

It has been four months since we received a letter from Mr. Donald L. Bohannon, Acting Chief of the Army BRAC Atlanta Field Office, on the Army's evolving definition of "regulatory closure" at Fort Sheridan. Since that time, U.S. EPA has adjusted its regulatory role into an advisory capacity, based on the direction provided in the FORSCOM letter.

As Landfill 6&7 construction activities draw to a close, we still do not understand all the steps the Army intends to use to obtain our "concurrence". The purpose of this letter is to facilitate dialogue on this matter, by providing guidance on some of the things U.S. EPA might expect to see before it can provide the concurrence the army says it is expects at Ft. Sheridan.

Our views are based on some assumptions which we still assume to be true:

1) The Navy and Army Reserve desires unrestricted reuse of their property up to the landfill cap boundary.
2) Landfill 6&7 will be considered construction complete as Kemron has built it, and our concurrence will not be conditioned upon additional response actions by either the Navy or Army Reserve.
3) DoD will continue to adequately fund all aspects of operation and maintenance of Landfills 6&7, including coastal engineering features, into the future.
4) The Army is not seeking either an OPS determination, Superfund NPL-NFA status, or FOST comments from U.S. EPA. Conversely, any concurrence we provide to the Army does not provide inferential approval of these CERCLA milestones.

From U.S. EPA's perspective the Army would need to produce at least three additional primary CERCLA documents in order to provide the necessary information to support a "decision document concurrence". First, a Remedial Action Implementation (RAI) Report must document all construction activity in sufficient detail to demonstrate protectiveness and conformance with the approved design. Second, and as your June letter points out, an Operation and Maintenance Plan must be drafted and approved. Third, we are expecting to see the Army issue a Final Proposed Plan before releasing another Decision Document. Your terminology may vary and other support documents will be thrown into the mix, but these three documents represent the major remedial decision points.

The following is a list of major issues that we expect to see addressed in the primary review documents.

<u>State ARARs</u>
We appreciate the improved emphasis by the Army in the last few months to respond to State concerns about applicable or relevant and appropriate requirements (ARARs). As a threshold NCP requirement, along with the obvious principle of public health protection, ARARs must be met first.

> Many of the clay cover materials were approved by the Army for construction prior to being approved by the State. The RAI Report must document all the necessary State characterization and retroactive State approvals.
>
> The disposition of cover materials on-site was a matter of ongoing discussion and concern. Locations and management of stockpiles during construction should be thoroughly documented. Some initial soil shipments were rejected and segregated; the disposition of these materials should also be documented.
>
> The demolition debris stockpiles on the LCFPD property were observed to have been disturbed and reworked shortly after LF 6&7 construction began. Written documentation (we suggested that a letter be obtained from the LCFPD) that none of these demolition waste materials were used on the landfill cap, should be included in the report.
>
> A groundwater monitoring plan needs to be submitted by the Army and approved by the State. After approval, at least least four rounds of validated sampling, over at least one year, must be provided which shows no groundwater contamination exists.

<u>Air Emissions</u>
This issue goes beyond State ARARs, to the extent that it represents the primary risk driver from the federal CERCLA perspective (due to unrestricted reuse at the landfill boundary). Those concerns are based on a very limited 12 year-old dataset. New cancer slope factors being considered by the agency for TCE might increase our risk assessment concerns, depending on the actual compounds and concentrations found in the gas now. There might also be new vapor intrusion issues that need to be evaluated.

Applicable State regulations are written from the perspective of methane explosive safety, not so much from toxic air emissions. In fact, it is very rare in Illinois for homes to be located adjacent to landfills, and the regulations actually prohibit new landfill siting within 500 feet of a residence.

The Army has still not responded completely to our November 27, 2001 comments on its October 2001 Draft Air Monitoring and Modeling Report, (the report was never finalized). The RAI Report, or other documentation, must respond to the issues raised in our letter regarding measures taken during construction to protect the public health of nearby Navy residents.

The construction integrity of the LF 6&7 cap was considered essential to our ability to concur with the Army's Interim Action Decision Document. After all, what's the point of building a cap with a state-of-the-art collection and flare system, if the cap leaks? This is why we have expressed concern about some of the Army's construction decisions. In order for us to officially concur with what you have done, the RAI Report needs to document all design changes, any problems that have occurred, and all corrective measures that were offered up internally and to the regulators during construction. We expect these issues to be fully and factually described, and then discussed from the standpoint of individual and cumulative affect on the protectiveness of the cap, in quantitative risk assessment terms. These issues include but are not necessarily limited to:

Rocks - The report needs to thoroughly document the management and disposition of all off-spec rocks, clay boulders and other debris that were brought onsite, either used in construction of the cap or screened out and used as general fill. The approved clay specification prohibits rocks larger than 2" in the cap. DOD's own current specifications set the maximum at ¾".

Grading Errors - Any elevation survey errors resulting in ponding of surface water or other drainage problems, along with followup patching and repairs should be documented. It is especially critical to document repairs to level areas where even small depressions might cause flooded low spots in the gas collection layer, possibly rendering those sections ineffective.

Wrinkling/Folding Liner - There were many instances of excessive wrinkling and compression of liner materials observed during construction of the cap. The report should document how the 3" maximum amplitude set by the Army was overseen and enforced.

GCL Freeze/Thaw - The winter of 2002-2003 was unusual in that the site experienced multiple rounds of freeze-thaw with very little snow cover. Much of the landfill only had one foot of clay cover during that time. The RAI report should discuss the possible significance of this freezing on the partially constructed cap and plastic leachate/gas collection lines.

GCL/Rain - GCL was not kept indoors during construction, and so there was at least one rainfall event resulting in premature hydration of stockpiled material. The RAI report must document disposition of all material and corrective actions taken by the Army, consistent with the measures spelled out by the manufacturer to protect the GCL performance warranties.

GCL/Stormwater - Stormwater damage during construction of the LF 7 east slope resulted in extensive GCL hydration damage during July and August 2003. Large sections of the east slope liner were replaced (possibly as much as an acre). The RAI report must document all incidents along with all corrective actions taken to repair the damage.

Lake Michigan Shoreline Protection

From our April 4, 1997 comment letter to the Army on the Draft LF 6&7 Decision Document (let me know if you need a copy):

> *"The U.S. EPA recognizes that it is very unusual for a sanitary landfill to have been constructed on the coast of Lake Michigan. In its discussions about this issue the BCT has learned that Landfills 6&7 are located on an historically erosional section of shoreline. U.S. EPA will insist that state-of-the-art designs for erosion controls are incorporated this remedy, and that the Corps of Engineers is committed to long-term maintenance of these controls."*

The U.S. EPA position has not changed. We will not concur with the final Decision Document unless the Corps of Engineers certifies that the erosion controls for LF 6&7 are protective, and they commit to maintain them.

The Illinois shore of Lake Michigan is almost completely engineered; any parts that are not are highly erosional. We normally defer to the Army Corps of Engineers expertise in coastal engineering in this area. Our ongoing concern is that FORSCOM disassociated itself from the Corps on this project two years ago and the Army has yet to consult with the regulators how the inevitable shoreline erosion will be managed.

Summing up, 1) the RAI Report needs to describe the shoreline protection structures that have been constructed or modified in detail, 2) the O&M Plan needs to describe how they will be maintained, and 3) the Decision Document must spell out contingency criteria and response actions, should significant erosion occur.

Institutional Controls

To a large degree LUCs are an ARAR issue at Ft. Sheridan, as the State Requirement for an approved LUC MOA and State LUC Implementation Plan will probably address our concerns. We are concerned, however, that almost six months has gone by since the Army received State comments on its Draft MOA and significant non-regulator policy differences are still open. These will all need to be resolved before we can concur that a remedy is protective, in any location where the Army is leaving waste in-place.

Design vs. As-built Cover Elevations

In spite of the extensive landscaping planned for the landfills, there was ongoing concern expressed by the public over their visual impact, in terms of overall height. This was a major motivation for the Army to go to the additional expense of using a Geocomposite Clay Layer (GCL), in lieu of additional clay. As a result Landfills 6&7 was one of the first

GCL landfill caps approved by the State of Illinois.

The reasons aren't clear, but the Army apparently allowed more soils from the removal action sites to be disposed under the cap than originally planned for in the design. Although the maximum overall landfill height was not exceeded, there were noticeable increases made to the average landfill elevations from the extra waste material. We note that the Army presented this information to the RAB, and no adverse comments were received at that time. The RAI report should discuss the modifications made to the design elevations, and should also document the community input obtained on the changes.

This letter is not intended to be a definitive list of everything the Army needs to put in its reports. It is intended to facilitate our approval by providing you with guidance about our current major policy concerns. We realize that due to the dynamic nature of this project, our concerns could change. For example, our concerns over landfill cap emissions might be addressed by adding comprehensive long-term monitoring methods, rather than trying to retroactively create documentation that might not exist. New land-use restrictions by the Navy and Army Reserve, backed up with enforceable LUCs, could be an alternative method to address our protectiveness concerns.

We hope this helps clarify what the Army needs to do to achieve the Landfill 6&7 Decision Document "concurrence" that it is expecting. Even if the Army decides not to request our concurrence, anything you can do to address our individual concerns will make it faster and less expensive for the Navy to eventually get Landfill 7 removed from the Superfund pipeline. These might also represent steps toward U.S. EPA concurrence with an OPS demonstration or property transfer (FOST) for the Navy or Army Reserve in the future.

The attached figure graphically presents some of the action steps discussed in this letter.

Please add this letter to the Ft. Sheridan CERCLA Administrative Record. If you have any questions, please let me know at 312 886-4843.

Sincerely yours,

W. Owen Thompson
Remedial Project Manager
Federal Facilities Response Section

cc: Brian Conrath, Illinois EPA
Judy Johnston, Ft. Sheridan RAB Co-Chair
Donald L. Bohannon, Atlanta BRACO FORSCOM
Col. Gary E. Johnston, ACE Chicago District
Mark Schultz, Naval Station, Great Lakes
Kurt Zacharias, 88th Army Reserve Support Ctr.
Gary Schafer, FFRS, U.S. EPA Region 5
Joshua Barber, U.S. EPA HQ FFRRO

Exhibit O

Landfill 7 East Slope Erosion Protection Key at Toe of Slope Drawing, From Parsons, Dated September 3, 2003, Letter from Brian A. Conrath, Remedial Project Manager, Illinois EPA, to Victor Bonilla, Army Forces Command, (Sept. 12, 2003)

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

1021 NORTH GRAND AVENUE EAST, P.O. BOX 19276, SPRINGFIELD, ILLINOIS 62794-9276
JAMES R. THOMPSON CENTER, 100 WEST RANDOLPH, SUITE 11-300, CHICAGO, IL 60601

ROD R. BLAGOJEVICH, GOVERNOR   RENEE CIPRIANO, DIRECTOR

(217) 557-8155
(FAX) 782-3258

September 12, 2003

Headquarters, Forces Command
Deputy Chief of Staff, G1
Attn: AFG1-BC (Victor Bonilla)
1777 Hardee Avenue, SW
Fort McPherson, Georgia 30330-1062

Re: Landfill 7 East Slope Erosion Protection
Key at Toe of Slope Drawing, from Parsons,
dated September 3, 2003

0970555001/Lake
Fort Sheridan (BRAC)
Superfund/Technical

Dear Mr. Bonilla:

The Illinois Environmental Protection Agency (Illinois EPA or Agency) is in receipt of the drawing entitled "Landfill 7 East Slope Erosion Protection Key at Toe of Slope, which was submitted by Parsons. It was dated September 3, 2003 and received by the Agency on September 4, 2003. This drawing provides Parsons' response to an apparent disagreement between the Army's contractor and Parsons over an area that was excavated at the toe of the east slope of Landfill 7 at Fort Sheridan. The Agency was asked to comment on this proposed design. Illinois EPA has reviewed this drawing and has several questions and comments. They are provided below.

1) First of all, why was this issue, if it began on August 15, 2003, not brought up at the BCT meeting on August 26, 2003? This appears to be a significant issue that requires BCT attention.

2) Why was the toe of the slope excavated in the first place? From an engineering standpoint, the toe of the slope is the most important spot in the entire landfill cap design, due to slope stability. This excavation was not called for in the 100% design document nor was it mentioned in the Record of Decision for this Interim Source Control Action. Was this a value-added engineering decision? If so, what was its purpose? A great deal of effort was put into designing the entire erosion control system for the east slope in the past. That effort included not only structural, but also hydrogeological engineering. Why did the Army allow its contractor to remove the existing shoreline revetments? What was

the purpose for placing the unusable clay/rocks from the cover soil clay screening process in this area of the beach?

3) How does the excavation at the toe of slope affect the Factor of Safety for slope stability? This requires a full engineering evaluation to determine the Factor of Safety for slope stability for a) the slope in its current condition, b) the slope with Parsons proposed fix, c) the final slope design, without Parsons' proposed fix, and d) any compromise being developed by Kemron. (The Factor of Safety was already calculated for the cap as it was designed.) These data must be calculated for comparison purposes, if a determination is to be made as to what is the proper and acceptable design for the toe of the east slope.

4) The submitted drawing is missing important details, such as how the proposed erosion protection structure will grade into the existing surface area in all directions and how stormwater and/or lake water during violent storms (due to wave action) will be handled on and around the affected area. Also, the Legend is not very clear in the copy received by the Agency. It is difficult to determine of what the different layers in the drawing are composed. This information needs to be provided before a proper analysis can be performed. Along this same line, how will these same issues be addressed if Parsons' design is not implemented, now that the toe of the slope has been excavated and backfilled?

5) Of what will the proposed geotextile be composed? Is it an HDPE geomembrane, a bi- or tri-planar drainage fabric, or something different? This is not apparent from the drawing. Please provide the specifications for the geotextile and the proposed rocks and boulders

6) The drawing is printed on paper that includes the U. S. Army Corps of Engineers Louisville District name and logo. Were they involved with this submittal? Please provide copies of their input to this design. Illinois EPA encourages the involvement of the U.S. Army Corps of Engineers in this design. They have considerable knowledge and expertise in shoreline erosion protection, and specifically for the East Slope of Landfill 7 at Fort Sheridan.

7) What would the effect of a rise of three or four feet in the Lake Michigan water level have on the current toe of the east slope? What affect would there have been if the excavation of the previously existing riprap revetment had not taken place? This is particularly important since the current lake level is approximately 2 feet below the historic average water level. A rise of three to four feet in water level would still be below the historical high water level in the lake. Add to that the possibility of waves of up to or greater than five feet and the effects of storm surge during storm events and you have the distinct possibility of waves encroaching upon the toe of the landfill. The design for this extremely important area becomes <u>the</u> critical part of the overall landfill cap. If the toe of

the slope begins to erode, the factor of safety for slope stability would also erode. This could cause the east slope of the landfill to fail and thereby the entire landfill cap to fail. Could it not? This appears to be Parsons' concern. Illinois EPA shares this concern.

8) Please provide a brief discussion of the reasoning behind each element of Parsons design, so that their purpose in the erosion protection design would be more apparent.

9) The Final Record of Decision for Landfills 6 and 7 must address the design of all of the erosion control structures protecting the east slope, as well as, long term monitoring for those structures. In addition, the Final ROD must also contain contingent actions for repairs or additional construction, should any part of the erosion control system fail.

These questions must be answered and the requested information provided before Illinois EPA can perform a complete analysis of the submittal. Please provide responses as soon as possible, so that resolution of this issue can be reached without unnecessary delay.

If you have any questions regarding this correspondence, you may contact me at 217/557-8155 or via e-mail at Brian.Conrath@epa.state.il.us.

Sincerely,

Brian A. Conrath

Brian A. Conrath
Remedial Project Manager
Federal Facilities Unit
Federal Site Remediation Section
Bureau of Land

BAC:RAC:H:\fortsh\LF6&7related\LF7Eslopetoemodrvw

cc: Owen Thompson, USEPA (SR-6J)
Mark Shultz, US Navy - EFA Midwest
Kurt Thomsen, Fort Sheridan EC
Chris Boes, USAEC
Kurt Zacharias, US Army Reserve
Tara O'Leary, USACE

Exhibit P

Army Oversight of the CERCLA Cleanup at Ft. Sheridan, Letter from W. Owen Thompson, Remedial Project Manager, U.S. EPA, to Victor Bonilla, Forces Command, Department of the Army, (Jul. 19, 2002)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, ILLINOIS 60604

REPLY TO THE ATTENTION OF: SRF-5J

July 19, 2002

Headquarters, Forces Command
Deputy Chief of Staff, G1
Attn: AFG1-BC (Victor Bonilla)
Ft. Sheridan BRAC Environmental Coordinator (BEC)
1777 Hardee Avenue, SW
Ft. McPherson, GA 30330-1062

RE: Army Oversight of the CERCLA Cleanup at Ft. Sheridan

Dear Mr. Bonilla:

The purpose of this letter is to express U.S. EPA's concern over the reduced Army oversight of its CERCLA cleanup responsibilities at Ft. Sheridan, Illinois. It has become clear over the last few months that the other six GFPR BRAC remediation contracts you are managing for FORSCOM are distracting you from your duties as the Ft. Sheridan Army BRAC Environmental Coordinator (BEC). Since you have expressed reluctance to drop your other projects and move here, we strongly encourage the Army assign a new BEC to Ft. Sheridan as soon as possible in order to get things back on track. We think that this person needs to be:

1) CERCLA response-authorized under the National Oil and Hazardous Materials Pollution Contingency Plan,
2) located at Ft. Sheridan or in reasonable commuting distance, and
3) assigned full-time to Ft. Sheridan until construction is complete and "regulatory closure" is achieved.

When FORSCOM made its decision one year ago to terminate its on-site BEC position and its intra-departmental agreements with the Army Corps of Engineers Louisville District, replacing its oversight with contractors, a number of questions and concerns expressed by Ft. Sheridan stakeholders have gone unanswered. I have watched patiently but with increasing disappointment as the spirit of teamwork and trust that we all worked so hard to achieve has evaporated. Project Team communications have worsened and policy disagreements between the regulators and the Army seem to be increasing as time goes on.

I did not intend to write this letter until prompted by FORSCOM management's response to my intentionally light-hearted email to Versar, Inc., regarding its continuing use of the former Army BEC's email address, "sheridanbec". I think that FORSCOM Headquarters' message demonstrates that it is misinformed about the true progress being made at Ft. Sheridan. At FORSCOM's request, I have "shared the email with my superiors". My superiors have recommended that I write this letter to you.

The real problem at Ft. Sheridan from U.S. EPA's point of view is that the Army has essentially disengaged from the BRAC table, leaving inherentlygovernmental decisions to be made by its contractors. While this is the Army's decision to make, it sets up a relationship that is markedly different than what is supposed to be in place at a BRAC site. Specifically, at a BRAC site, DoD (Army) is supposed to have an on-site BRAC Environmental Coordinator (BEC). This person is supposed to be the single point of contact for the DoD on the site for the regulators to negotiate with, just as our own RPMs are supposed to be (and in fact are) the single point of contact representing EPA. In fact, the Army had a very effective BEC at Ft. Sheridan for many years. The Army's decision to go with a fixed-price government contract to complete the work at Ft. Sheridan has basically replaced that on-site BEC position with a number of contractors with competing interests at the site. From the regulatory perspective this has become inefficient and creates a difficult environment for us to negotiate when no one appears to have any decision-making authority or is "in charge". Here are just a few recent examples of these difficulties:

1. We continue to receive work products from time-to-time directly from contractors with no guidance provided as to what the Army wants to have us comment on, or the deadlines desired.[a]

2. Important policy issues raised in our comment letters are ignored.[b]

3. Documents critical to understanding of the management of the cleanup are withheld from the regulators and the public, and our requests for them go unanswered.[c]

4. U.S. EPA is singled out by FORSCOM management for not maintaining a "team effort" for sharing its concerns about the GFPR process at a RAB meeting, but yet Illinois EPA and Department of the Navy (the current Landfill 7 landowner and the federal agency responsible for operating and maintaining land use in the future) have raised a similar universe of issues in more strident terms than U.S. EPA. [d, e, f]

5. FORSCOM claims that it works with the entire U.S. EPA and that the U.S. EPA RPM for Ft. Sheridan is the only one in the country that has questioned the Army GFPR privatization of its oversight responsibilities. In fact, my RPM counterparts in other EPA Regions have had experiences with the FORSCOM GFPR. One site of similar complexity that is experiencing similar problems is Ft. Devens, MA. [g]

Quoting from Alan Balliett's (FORSCOM, Ft. McCoy, Wisconsin, the previous Ft. Sheridan BEC) December 14, 2001 letter:

> *"I understand your concern about communication with all the parties involved. I believe we have made some significant strides in resolving this issue, but realize that there is further work required especially with those contractors who are not part of the GFPR contract. I ask your patience as we continue to refine the rules of engagement".* [h]

Mr. Balliett tried valiantly from 200 miles away to "refine the rules", but the new paradigm for the Ft. Sheridan BCT is still unclear.. Rather than operating as a project team, Ft. Sheridan meetings have taken on the tone of legal depositions, with U.S. EPA and Illinois EPA being questioned and tape recorded by Army contractors as other Army oversight contractors remain silent. At a recent pre-construction meeting, no employee representative from the Army, Navy, or Army Reserve was present.

Acknowledging that it is the Army's decision to make, U.S. EPA remains concerned that the absence of a response-authorized Army BEC will continue to inhibit BCT decision making and might have unnecessarily set the Ft. Sheridan remediation project up for failure, if regulatory concurrence is the desired outcome.

The Army should carefully consider this uncertainty when calculating the true "cost savings" of privatizing its Ft. Sheridan oversight. The enhanced federal oversight recommendations contained in the GAO report that I provided to the Army at the last BCT/RAB meeting were submitted in the sincere hope that the Army can avoid the expensive and politically embarrassing problems that U.S. DOE experienced when it experimented with privatizing its environmental cleanups.[2]

For seven years I participated in the one of the most professionally satisfying projects in my career; being part of the interagency Ft. Sheridan BRAC Cleanup Team (BCT) along with Illinois EPA's Paul Lake and the Army FORSCOM's Colleen Reilly. U.S. EPA has often touted Ft. Sheridan as an example of how well BCT process can work. Ft. Sheridan was (and still is) the first BRAC site in Region 5 to complete the transfer of all of its surplus property with full regulatory concurrence. Our hope is that with the critical BEC staffing change we are suggesting, our cooperative relationship with the FORSCOM at Ft. Sheridan can continue into the future.

Thank you for your prompt attention to this matter. I can be reached at 312 886-4843 if you have any questions.

Sincerely yours,

W. Owen Thompson

W. Owen Thompson
Remedial Project Manager
Federal Facilities Response Section

cc: Brian Conrath, Illinois EPA
Clarence Smith, Illinois EPA
Kurt Zaccharias, U.S. Army Reserve Support Command
Mark Schultz, Navy Great Lakes EFA Midwest
Arden J. Roberts, Director, FORSCOM HQ BRAC Div.
Tara O'Leary, Army Corps Louisville District
Hugh MacAlear, Army U.S. AEC REC for Region 5
Judy Johnston, Chair, Ft. Sheridan RAB
Timothy Drexler, EPA Region 5 FFRS Acting Chief
Gary Schafer, EPA Region 5 FFRS
James Mayka, EPA Region 5 RR Branch Chief
James Woolford, EPA HQ FFRRO
Dennis Gagne, EPA New England Fed. Facilities
Richard Seraydarian, EPA Region 9 Fed. Facilities
Mark Stephens, EPA Region 3 Fed. Facilities

Footnotes

The documents and communications referenced are part of the U.S. EPA Federal Facility Site Assessment Administrative Record for Ft. Sheridan, CERCLA Site ID#IL2210020838. Per the National Oil and Hazardous Material Pollution Contingency Plan (NCP), Section 300.800(b), U.S. EPA considers these items formative to the selection of the response action at Ft. Sheridan and if not already included, are furnished for placement in the Army's CERCLA Administrative Record:

[a] - Former Ravine Waste Extent Determination, Landfill 7 Ft. Sheridan, Illinois, IT Corporation, June 2002

[b] - W. Owen Thompson, U.S. EPA RPM for Ft. Sheridan, February 25, 2002 letter to Alan Balliett, Ft. Sheridan BEC, Comments on 90% Interim Design, Ft. Sheridan Illinois Landfills 6 & 7, Parsons Engineering Science, November 30, 2001

[c] - W. Owen Thompson, U.S. EPA RPM for Ft. Sheridan, November 20, 2001 letter to Alan Balliett, Ft. Sheridan BEC, Request to Place GFPR Contract into CERCLA Administrative Record

[d] - Electronic mail message from Arden J. Roberts, Director FORSCOM BRAC Office, U.S. Army to W. Owen Thompson, U.S. EPA Remedial Project Manager for Ft. Sheridan, June 21, 2002

[e] - Brian A. Conrath, Illinois EPA RPM for Ft. Sheridan, May 17, 2002 letter to Victor Bonilla, Ft. Sheridan BEC, Atlanta, GA, Significant Issues at Ft. Sheridan.

[f] - T.F. Berson, Commanding Officer, Department of the Navy, Engineering Field Activity, Midwest, June 24, 2002 memorandum to Commanding General, Army Forces Command (FORSCOM), Guaranteed Fixed Price Remediation Contract at Ft. Sheridan

[g] - Personal communication between W. Owen Thompson, U.S. EPA RPM for Ft. Sheridan and Mary Sanderson, Special Assistant to the U.S. EPA New England Regional Administrator at U.S. EPA Facilities Leadership Council Meeting, New York, NY, June 26, 2002.

[h] - Alan L. Balliett, Ft. Sheridan BEC, December 14, 2001 letter to W. Owen Thompson, U.S. EPA RPM for Ft. Sheridan, response to October 26, 2001 and November 1, 2001 comments on Army management of its Ft. Sheridan GFPR contract.

[i] - U.S. General Accounting Office, Observations on DOE's Privatization Initiative for Complex Cleanup Projects, Statement of Gary L. Jones, Associate Director, June 22, 2000, GAO/T-RCED-00-215

Exhibit Q

Review of Erosion Control Features for Interim Remedial Action Landfills 6 & 7, Fort Sheridan, Illinois, Charles W. Shabica, Ph.D., Charles Shabica & Associates, (Nov. 25, 1997)

Charles Shabica & Associates
345 Walnut Stree, Suite 201
Northfield, Illinois 60093
847-446-1436

DATE: December 2, 1997

TO: Robert Fileccia, U.S. Army Corps of Engineers
cc: Michael Chrzàstowski, IL State Geological Survey
Charles Johnson, U.S. Army Corps of Engineers
Colleen Reilly, U.S. Army Corps of Engineers
Mary Tibbetts, U.S. Army Corps of Engineers
Bill Zackley, Stone Webster

FROM: Charles W. Shabica, Ph.D.

SUBJECT: The Fort Sheridan Report

Please find the enclosed report: "Review of Erosion Control Features for Interim Remedial Action Landfills 6 & 7, Fort Sheridan, Illinois, 11/25/97." We look forward to meeting with you to discuss this project.

[Decision Document (DD) for Interim Source Control Action for Landfills 6 and 7 at Fort Sheridan, ILLINOIS

[Prepared for: U.S. Army Corps of Engineers Louisville, Kentucky

April 22, 1997

REVIEW OF EROSION CONTROL FEATURES FOR INTERIM REMEDIAL ACTION LANDFILLS 6 & 7, FORT SHERIDAN, ILLINOIS, 11/25/97

1. INTRODUCTION & EXECUTIVE SUMMARY

Charles Shabica & Associates has reviewed *Fort Sheridan Landfills 6 & 7 Interim Remedial Action - Phase 1 Design Analysis Report Final June 1997*. It is concluded that the proposed plan to protect coastal landfills from the erosive forces of Lake Michigan storm waves does not meet the requirement for long-term (30+ year) beach protection. A breakwater/beach is recommended that meets these requirements and includes two additional benefits. The breakwater/beach will also function as a broad sand-filter for runoff from the system. Further, beaches allow for safe user-friendly access to the lake.

Review: Current Plan - Proposed Revetment & Steel Sheet Pile Wall

The current plan, designed to protect the bluff only, includes a quarrystone revetment and steel sheetpile wall at the lakeshore (Appendix 1A - Sheet 30, Appendix 1B - Sheet 31). The technical review of the revetment specifications (Section 2) shows the structure to have inadequate toe and crest elevations. Specifications for a revetment that will provide 30+ year bluff protection are listed as "Review" and are compared to the current plan in Appendix 2A, Drawing 1 (10/8/97). Estimated construction cost for the review plan is approximately $906,000 for a 360 foot wide revetment with proper crest and toe elevations. However, the current and review plans do not meet the requirement for beach protection and are therefore rejected.

Alternate Plans:

Two shore protection options were considered for this site that meet the additional requirement of beach protection. These include a groin held beach and a breakwater held beach. We rejected the groin option because the beach would be built in the zone of active lakebed downcutting. With a steepening nearshore lakebed profile, groin fields in adjacent areas are rapidly losing their effectiveness at holding beaches (Shabica & Pranschke, 1994; Charles Shabica & Associates, 1997). For example at Fort Sheridan several beaches to the north are held by groins and have narrowed to the point where the bluffs have begun to erode (Appendix 2D, 5/23/97 air photo).

Recommended Plan:

A nearshore breakwater constructed at a depth below the zone of active lakebed downcutting fulfills all the requirements for 30+ year protection of the landfills and a beach. This "Alternate Plan" is shown conceptually in Appendix 2B, Drawing 2 (10/8/97) and Appendix 2C, 1991 air photo. Estimated construction cost for this system is $1,256,000.

2. TECHNICAL REVIEW OF CURRENT PLANS

Using the Army Corps of Engineers *Automated Coastal Engineering System* (ACES 1.07) and other sources, the following specifications were developed for this site (see Appendix 3A) and are compared to the current plan (elevations are based on NGVD1983 and can be converted to IGLD1985 by subtracting 0.6 ft).

Revetment Specifications	Review	Current Plan
Crest Elevation:	596.3 ft (IGLD 595.7 ft)	586 to 590 ft
Toe of Revetment:	572.5 ft (IGLD 571.9 ft)	582 to 584 ft
Average Armor Size:	4.5 tons	467 lbs
Core stone:	900 lbs	
Revetment Thickness:	11 ft	3.32 ft
Slope:	1:1.5	1:3
Tons/linear ft:	29.6 (includes rubble fill)	3.1

Assumptions:

• Design High Water:	583.8 ft* (IGLD 583.2 ft)	582.9 ft
• Design Low Water:	578.1 ft* (IGLD 577.5 ft)	
• Existing clay till elevation at bluff toe:	576.5 ft (IGLD 575.9 ft), soil boring #MW6d	
• Near shore sand volume	72 m^3/m of lakeshore***	
• 30 yr lake bed erosion at toe	6.5 ft**	
• Design depth at toe - below HW (Ds)	11.3 ft	4.9 ft
• Wave height at Toe:	8.8 ft (Hi)	4.66 ft (Hb)
• Near shore Slope:	1:20***	1:60
• Maximum Wave Period:	10.5 seconds ****	10.5 seconds
• Stone Porosity	37%	40%
• Stone cost, placed by lake barge	$85/ton	

* DHW includes 2 ft storm setup, DLW = Low Water Datum
** 3.5 ft sand and gravel (thickness varies) plus 3 ft clay till, Nairn, 1997
*** Shabica & Pranschke, 1994
**** Resio & Vincent, 1976

Discussion:

Lakebed erosion, active in water depths of 10 feet or less, was not included as a design component of the current plan (Appendix 2A). The Fort Sheridan lakeshore is considered sediment starved (less than 72 cubic meters of sand cover per linear meter of lakeshore) and is underlain by a highly-erodable, glacial clay-till (Shabica & Pranschke, 1994, Appendix 3B, 3C). Calculations for this site show an irreversible lowering of the nearshore lakebed clay of approximately 3 feet over a 30 year period (Nairn, 1997). According to Nairn, approximately 200 meters of sand cover per meter of lakeshore (out to a depth of 4 meters) is necessary to protect the underlying cohesive profile under most conditions. The lakebed downcutting combined with seasonal loss of the thin (3 foot to 4 foot thick) sand and gravel cover will result in a 10 foot exposed section of bluff below the toe of the *current plan*. *Without toe protection, the revetment will fail.* This could expose the upper 2/3 of the steel sheetpile wall to storm wave impact. If the sheetpile wall fails, the bluff fill and leachate interception ditch will then be vulnerable to wave attack. The lowering of the nearshore lakebed will also affect the height of the design wave. As the waves impacting the structure are depth limited, an 8.8 foot design wave is predicted. Runup calculations show a crest elevation of 596.3 feet, 6 feet to 10 feet above the proposed revetment crest. Storm waves overtopping the structure will impact the leachate interception ditch that has a crest elevation of 594 feet to 595 feet.

3. RECOMMENDED ALTERNATE PLAN: 30 YR BEACH PROTECTION

We recommend a quarrystone breakwater/beach system be designed for this site as the revetment plan and the groin held beach option do not fulfill the design requirements of 30+ year storm wave erosion protection for the landfill site and adjacent beach (Appendix 2B, 2C). The existing sand and gravel beach at this site is narrow, is typically less than 3.5 feet thick (Shabica & Pranschke, 1994) and provides minimal wave protection. An enlarged coarse-sand engineered beach protected by 2 nearshore breakwaters is the only viable solution to beach and bluff erosion at the Landfill 7 site as regional beach nourishment is unlikely within the next 10 years (Johnson, 1997).

Breakwater protected coarse-sand beach systems have a proven track record on the Illinois shore of Lake Michigan (Baird, 1989; Chrzastowski, 1996; Shabica, 1996). They provide long-term beach and bluff protection and can be designed for later expansion to adjacent sections of lakefront property. At the Fort Sheridan site, two breakwaters approximately 125 feet and 150 feet long are recommended to protect the landfill and its flanks. With a wide, stable beach, the sheetpile wall (Current Plan) would no longer be necessary to protect the landfill from storm waves. To contain the site and minimize along shore sand transport, each breakwater should be connected to the land by a groin. The north groin will also separate the recreational beach from runoff from the drop structure adjacent to the north.

For long-term stability, the breakwater toe elevation should be at or below the depth limit of 30 year lakebed erosion, elevation 568.1 feet (Appendix 2B). This is approximately 175 feet off the present lakeshore. A bathymetric survey should be conducted to confirm nearshore lakebed elevations. Although the low crest elevation of the breakwater (588.6 feet) will allow for some overtopping, a broad coarse (birdseye) sand beach will prevent storm waves from reaching the bluff.

It is estimated that construction costs for two quarrystone breakwaters, two sheetpile groins and coarse sand fill will be approximately $3,490 per linear foot of lakeshore. Protection of the landfill and its flanks (360 feet wide) with this system will cost approximately $1,256,000. This estimate includes a quarrystone channel structure constructed between the north groin and the existing concrete "pier." The channel will choke with sand during dry weather and will divert storm runoff from the base of the concrete drop structure to the lake. To expand the breakwater system to the entire 1,050 ft coastal cell bounded on the north and south by existing steel sheetpile groins, the construction cost is estimated to decrease to $2,750 per linear foot of lakeshore.

4. REFERENCES:

W.F Baird & Associates and Warzyn Engineering, 1986, *Shoreline Development at Forest Park, Lake Forest, Illinois, Model Studies*, Unpublished Final Report to the City of Lake Forest.

Chrzastowski, M.J. and C.B. Trask, 1996, *Review of the City of Lake Forest Final Report for the 1995 beach and nearshore monitoring program, Forest Park Beach, Lake Forest, Illinois*: Illinois State Geological Survey, Open File Series, 1996-6, 57 p. plus eight appendices.

Johnson, Charles, 1997, USACE, Chicago, personal communication.

Nairn, Robert B. 1997. *Cohesive Shores.* Shore & Beach Vol. 65 No. 2: 17-21.

Resio, Donald T. and Charles L. Vincent. 1976. *Design Wave Information For The Great Lakes: Technical Report 3, Lake Michigan.*

Shabica, Charles and Frank Pranschke. 1994. *Survey of Littoral Drift Sand Deposits Along the Illinois and Indiana Shores of Lake Michigan*: Journal of Great Lakes Research, vol. 20, no.1.

Charles Shabica and Assoc., 1997, *Lake Bluff Beach Monitoring and Mitigation Report 5*, to US Army Corps of Engineers, Chicago District.

1991 Air photo of Fort Sheridan showing location of recommended alternate plan: breakwater protected beach system.

Appendices

1A Detail, Sheet 30, Current Plan

1B Detail, Sheet 31, Current Plan

2A Drawing No. 1, 10/8/97, Comparison of Current and Review revetment plans

2B Drawing No. 2, 10/8/97, Recommended Plan: Breakwater/Beach

2C Air Photo of site showing design concept for Recommended Plan

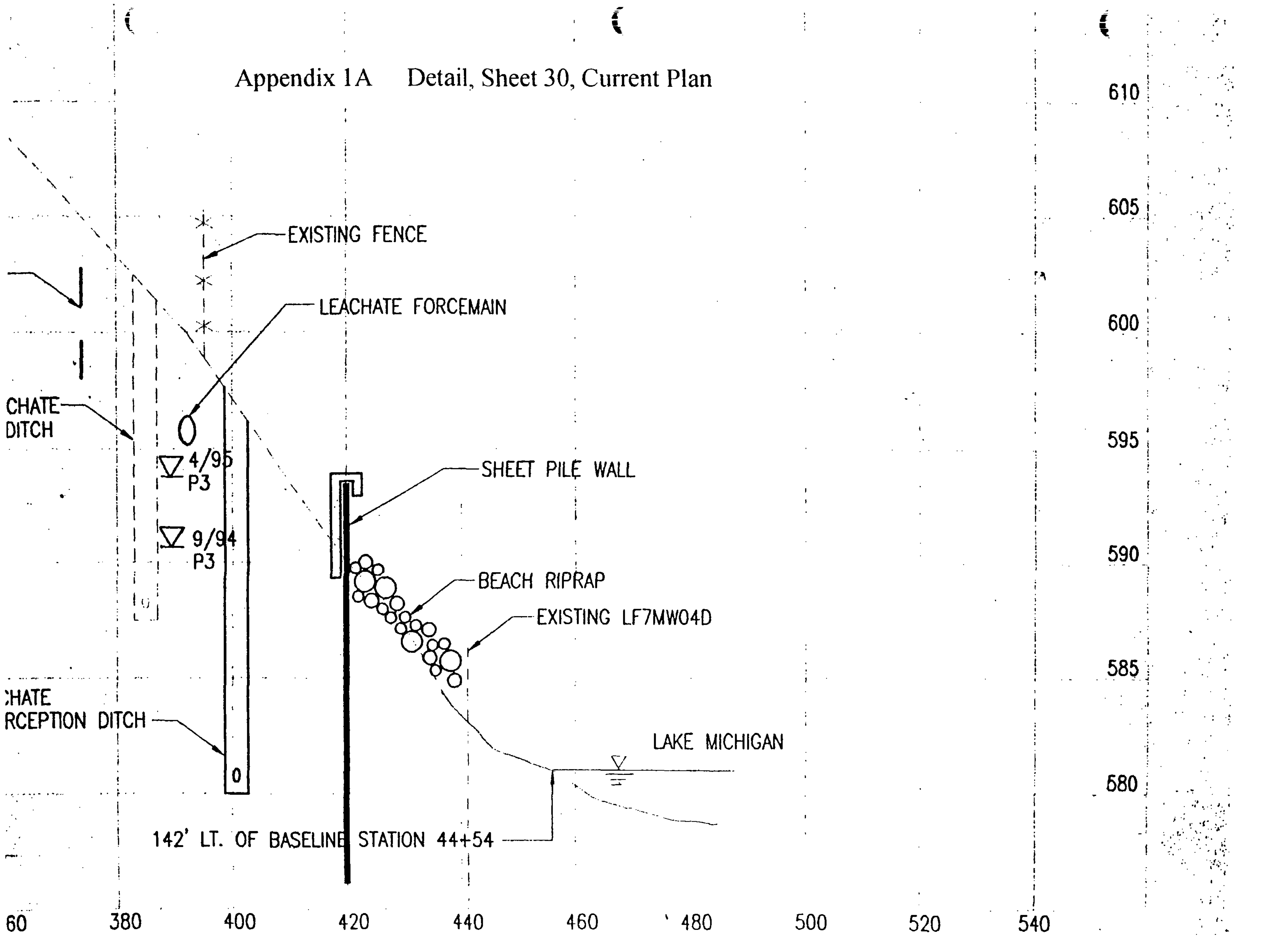
2D Air Photo of narrow beach and eroding bluff north of site

3A Wave Runup and Armorstone Calculations

3B Data: littoral drift sand deposits along the Illinois shore of Lake Michigan

3C Sand thickness – Fort Sheridan boat launch ramp 7/24/90

Appendix 1A Detail, Sheet 30, Current Plan



Appendix 1B Detail, Sheet 31, Current Plan

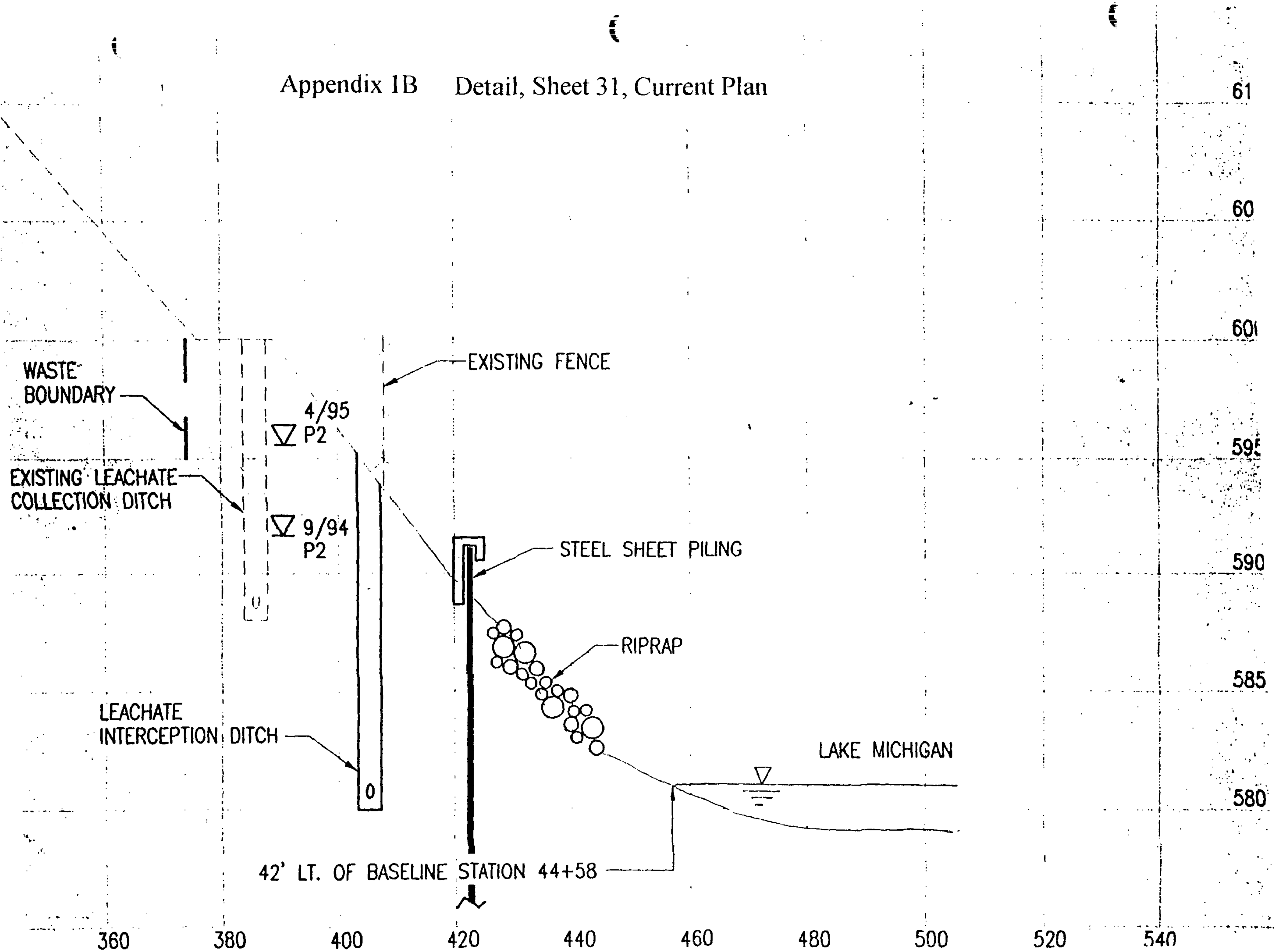


Exhibit R

Response to Comment by David Liu on the Draft Report, Design of Shoreline Protection, Interim Remedial Actions at Landfills 6 and 7, Fort Sheridan, Illinois, Rev 5/22/98, Charles Shabica, Charles Shabica & Associates, (Aug. 5, 1998)

DEPARTMENT OF THE ARMY
HEADQUARTERS, FORT McCOY
FORT McCOY, WISCONSIN 54656-5146

REPLY TO
ATTENTION OF

August 19, 1998

BRAC Environmental Coordinator

Mr. David Liu
340 E Oakdale Avenue
Lake Forest, IL 60045

Dear Mr. Liu,

Enclosed is a response to your comment on the Draft Report, Design of Shoreline Protection Interim Remedial Actions, Landfills 6 & 7, Fort Sheridan, Illinois, Rev 5/22/98.

I hope this response adequately addresses your question. I appreciate your review of the design documents and for your continued active engagement in the fort's environmental restoration activities.

If you have any questions, please feel free to contact me at 847-266-6323 or Dr. Charles Shabica at 847-446-1436.

Sincerely,

Colleen Reilly
BRAC Environmental Coordinator
Fort Sheridan

Enclosure

Comment on

DRAFT REPORT, DESIGN OF SHORELINE PROTECTION
INTERIM REMEDIAL ACTIONS AT LANDFILLS 6 AND 7
FORT SHERIDAN, ILLINOIS, REV 5/22/98

According to Section 2, the design life of the system is given as 30 years. The assumptions shown in Section 3 are presumably all 30-year values. However, it is not clear how these 30-year design values are selected -- based on long-term measured data or calculated from such data. In particular, there is no reference in Section 3 for the design wave height, and it may be from measured wave data (usually not available for a period long enough to arrive at a 30-year design height) or based on techniques such as hindcasting using a 30-year extreme weather condition from climatological data (usually available for a much longer period). Section 6 provides further discussions on wave climate, but still there is no indication how the 30-year significant wave heights reported in the references were obtained.

It is likely that more refined assumptions would not have any significant impact on the shoreline protection design. However, I thought I should raise the question.

David Liu
7/21/98

Charles Shabica & Associates
345 Walnut Street, Suite 201
Northfield, Illinois 60093
847.446.1436, Fax 847.446.0728

DATE:	August 5, 1998		
TO:	Bob Fileccia, CoE Louisville	Fax:	502-582-5168
COPY:	Colleen Reilly, BRAC	Fax:	414-332-4592 ~~847-266-3904~~
	William Zackely, Stone & Webster	Fax:	303-741-7857
FROM:	Charles Shabica		
PAGES:	1		

SUBJECT: References for design wave heights, response to comment by David Liu on Draft Report, Design of Shoreline Protection Interim Remedial Actions at Landfills 6 and 7, Fort Sheridan, IL

Two sources of wave data for design wave height were used:

Hubertz, Jon M. et al., 1991, *Hindcast Wave Information for the Great Lakes: Lake Michigan,* WIS Report 24, CERC, USACE Waterways Experiment Station. Statistical analysis of 32 years of measured data (1956 – 1987).

Resio, Donald T. and Charles L. Vincent. 1976. *Design Wave Information For The Great Lakes: Report 3, Lake Michigan.* Technical Report H-76-1, USACE Waterways Experiment Station. Historical wind data from 6 stations along Lake Michigan (1905 – 1976) inputted to numerical hindcast model provides significant wave heights for 5-, 10-, 20-, 50-, and 100-yr return periods. 30 year return period was extrapolated from 20- and 50-yr.

Exhibit S

Landfill 7 Erosion Protection Based on 30-year Recurrence Interval Storm, Letter from Colleen Reilly, BRAC Environmental Coordinator, to Elizabeth Zeller, City of Highland Park Lakefront Task Force, (Oct. 8, 1998)

DEPARTMENT OF THE ARMY
HEADQUARTERS, FORT McCOY
FORT McCOY, WISCONSIN 54656-5146

REPLY TO
ATTENTION OF

October 8, 1998

BRAC Environmental Coordinator

Ms. Elizabeth Zeller
City of Highland Park Lakefront Task Force
1707 St. Johns Avenue
Highland Park, IL 60035

Dear Ms. Zeller:

I write in response to several questions you relayed to Mr. Bill Zakely of Stone & Webster on September 10, 1998. Stone & Webster is working under contract for the Army on the Landfills 6 & 7 Restoration Project. Responses to your questions are provided below:

1. Q: Have studies of the effect of the planned erosion control on the natural sand progression along the beach to the south been done?
A: The proposed structures will be approximately the same distance offshore as the existing groins in this region. In addition, the new beach is designed to bleed 20% of its sand fill (2500 tons) into the littoral stream.

2. Q: What recurrence interval storm is the design based on?
A: It is based on a 30 year storm.

3. Q: Is there a location map that shows the shoreline erosion control features relative to Landfill 7?
A: Appendix 2C of the *Design of Shoreline Erosion Protection Interim Remedial action at Landfills 6 and &, Fort Sheridan, 11/25/97* report is an aerial photo of Landfill 7. "Alternate Plan" shows the approximate location of the erosion control features.

4. Q: What impact will the planned shoreline erosion control features have on properties to the south?
A: See response to the first question above. Additionally, the beach immediately to the south is held by a steel sheet pile groin ("Existing Groin" in 1992 aerial photo). The new shore protection system will have a new groin on its south flank that will be "wave softened" with a quarrystone revetment.

If you have any additional questions, please feel free to contact me at (847) 266-6323. Thank you for your review.

Sincerely,

Colleen Reilly

Colleen Reilly
BRAC Environmental Coordinator
Fort Sheridan

Exhibit T

Change in Definition to Regulatory Closure, Letter from Victor Bonilla, Forces Command, Department of the Army, to Brian Conrath, Illinois EPA and Owen Thompson, U.S. EPA, (Sep. 24, 2002

DEPARTMENT OF THE ARMY
Headquarters, Fort McPherson
Fort McPherson, Georgia 30330-1062

September 24, 2002

Environmental Division

Mr. Brian Conrath
Illinois Environmental Protection Agency
1021 N. Grand Avenue
Springfield, Illinois 62794-9276

Mr. Owen Thompson
Superfund Federal Facilities Response Section
US Environmental Protection Agency - Region V
Attn: SFR-5J
77 West Jackson Boulevard
Chicago, Illinois 60604-3590

Subject: Fort Sheridan Environmental Restoration Project
Fort Sheridan GFPR Contract Regulatory Colsure

Dear: Mr. Conrath and Mr. Thompson:

Al Balliet introduced a definition of regulatory closure at the February 7, 2002 BCT meeting. This definition has been coordinated through the FORSCOM environmental lawyer and the Environmental Law Division at HQDA. The comments received from the regulators during the February BCT were also incorporated. The resulting definition reads:

"The selected remedy will protect human health and the environment, meet applicable, relevant, and appropriate rules and regulations, and is in place and working. Long-term monitoring will be in place and working. Land-use controls are in place. Furthermore, (1) The Army will not obtain covenants for the Navy and the Reserve. (2) The "remedy in place and working" portion of regulatory closure definition does not mean the GFPR contractor will obtain EPA certification that the remedy is working properly and successfully IAW CERCLA 120 H (3)."

Please review this definition in preparation for a discussion of regulatory closure at the upcoming BCT meeting being held on September 27, 2002.

Sincerely,

for

Victor Bonilla
Forces Command
BRAC Division